THE ECONOMIC BENEFITS OF MILITARY BIOFUELS

Report Prepared

for

Environmental Entrepreneurs

by

Joel S. Yudken, Ph.D.
Principal, High Road Strategies, LLC
104 N. Columbus Street, Arlington, VA 22203
(703) 528-7896 (o) • (703) 980-8122 (c)
jyudken@highroadstrategies.com • www.highroadstrategies.com

November 10, 2012

Table of Contents

EXECUTIVE SUMMARY

E2 supports the development of an American advanced biofuel industry as a key component of a clean energy economy. We are tracking the growth in this sector, and supporting federal policies to enhance biofuels expansion, including the biofuel targets set by the U.S. Department of Defense, (DoD)

DoD has set aggressive goals for incorporating advanced biofuels into the Air Force and Navy fuel mix to enhance mission capacity and security. At the same time, the military's biofuel requirements create an important market signal for the growth of the industry.

E2 commissioned a study to assess the impact of DoD's biofuels investments and demand signal on the growth of domestic clean fuels production and the potential economic benefits to the U.S. economy. The report found that the value chain of the nascent biofuels industry in response to these military targets will create thousands of jobs and billions of dollars in new revenue, especially in states or regions with biorefineries.

The impacts of the military's biofuel strategy transcend the defense market by attracting private capital into technology development and biorefinery construction, accelerating the scale up and deployment of biofuels. Biofuels will become increasingly cost competitive as production volume increases, providing clean fuel choices for the civilian sector, particularly in the commercial aviation industry.

Conclusions

- Meeting DoD's biofuel targets will directly generate between $9.6 and $19.8 billion of economic activity by 2020.
- Between 14,000-17,000 new jobs will be created by 2020. If measured on a job-year basis, the total number of jobs created would be more than twice that amount.
- Of these jobs, 3,000-5,000 will be permanent rural agricultural jobs from biomass production, and about 1,200 will be in biorefinery operation. An additional 10,000 jobs will be created from biorefinery construction.
- These economic and job impacts will be broadly distributed geographically, with the greatest benefits to states that create the strongest incentives for biorefineries.
- In order to meet the military's cost and volume targets, advanced biofuel companies are leveraging $3.4 billion of

private capital invested since 2007 to build new commercial facilities.

- Military demand is helping to shape the early market and scale the advanced biofuel industry

Clean Fuels

Advanced biofuels are renewable, liquid transportation fuels that can replace traditional gasoline and diesel while creating significantly lower greenhouse gas (GHG) emissions. These fuels contain a similar molecular structure, and are therefore compatible with existing infrastructure. Such fuels are commonly referred to as "drop-in" fuels.

Advanced technologies in public transportation and vehicle electrification are critical to reducing our fossil fuel demand. However, there will be a long-term demand for liquid fuels for industrial, shipping and aviation needs which must be addressed in part by encouraging the development of sustainable, domestic fuels.

E2 recently analyzed the state of the advanced biofuel market, and found that 165 domestic companies are positioned to provide 1.6-2.6 billion gallons of fuel to the U.S. market, given appropriate market signals and support from regulations such as the Renewable Fuel Standard and Low Carbon Fuel Standard.

Department of Defense Clean Energy Goals

As part of its national security strategy, the Department of Defense is actively pursuing energy efficiency and clean energy initiatives, both to reduce the military's total energy needs and to ensure domestic sources of energy and fuel. The Navy and Air Force lead the clean fuel initiatives, with goals to replace half their consumption of petroleum-based fuels with alternatives by 2016 and 2020, respectively. This is backed by a joint investment from the Navy, DOE and USDA to provide $510 million over a three-year period for the development of advanced biofuels compatible with the military's infrastructure. The Air Force and the Navy's goals will jointly require about 770 million gallons of advanced biofuel capacity.

Direct Economic Impacts

With the variety of technology platforms and feedstocks that can be used to produce advanced biofuels, this nascent industry has many alternative pathways to success. However, this versatility also makes economic modeling inherently difficult. The cost of construction, feedstock supply and operation vary significantly based on the specific fuel pathway.

In order to accommodate these many options our report casts a wide net around the upper and lower limits of the cost components of the major value chain sectors. This approach provides a 'first order' assessment as to the economic impacts of DOD's programs, no matter the specific biofuel combination used to meet military demand.

Total revenue generation will be on the order of $9.6 billion -$19.8 billion by 2020. Of that, roughly $6 billion will be attributable to construction, and an additional $1.6 billion to $4.9 billion will be attributable to feedstock production.

Job Creation

14,000 to 17,000 jobs will be created between 2013 and 2020 for biorefinery construction and operation, fuel distribution, and feedstock production. These jobs are heavily concentrated in the agricultural sector, with about one-third coming from biomass production.

Because the study focuses exclusively on economic activity related to the military's specific targets, it does not reflect the fact that biorefinery construction will scale up to meet the demand of additional end-users, such as the civil aviation industry, resulting in significantly greater job creation.

Regional Impacts

Between 2013 and 2020, a typical 50 million gallon biofuel plant can add the following to a rural economy with biomass resources:

- 750 construction jobs
- 491 permanent jobs
- $1.2 billion in output

In addition to these direct contributions, the plant would have indirect and induced economic benefits, a significant portion of which would remain within the regional economy. The study calculates the value of direct, indirect and induced benefits as potentially reaching $3.8 billion of output and 21,000 job-years over the eight-year period.

As advanced biofuels can use existing petroleum distribution infrastructure, biorefineries could be located in just about any state or region of the country to supply the military or civilian markets. What will determine the location of biorefineries are local incentives and biomass supply. Advanced biofuels may come from a variety of feedstocks found across the country – energy crops, agricultural residues, waste materials, algae and more – thus providing a highly distributed opportunity for biorefinery location.

Beyond Military

The larger implication of military biofuels initiatives is the establishment of an industry that can also serve the private sector. This is analogous to what the military has done with other technologies such as Global Positioning System (GPS) or the Internet, technologies with ramifications that have found applications far beyond military use.

Already, the aviation industry is actively exploring the use of advanced biofuels for civil aviation. The military's leadership provides a platform for scaling the industry, accelerating adoption and extending advanced biofuels into the civilian market. For example, the Pentagon is partnering with the Commercial Aviation Alternative Fuels Initiative, Air Transport Association and American Society for Testing Materials International to promote the development, certification, commercialization and marketing of alternative fuels. This could be transformative for the civilian aviation industry providing clean fuels at affordable prices, while reducing greenhouse gas emissions.

About E2

Environmental Entrepreneurs (E2) is a non-partisan national community of 850 business people who believe in protecting the environment while building economic prosperity. Our mission is to provide a platform for an independent business voice to promote environmentally sustainable economic growth. E2 represents entrepreneurs, investors and professionals from every sector of the economy. We work at both the state and national levels through bipartisan efforts. Learn more at www.e2.org

PROBLEM OVERVIEW

In 2007, a U.S. Air Force (USAF) report on biofuels concluded that "biologically produced aviation fuel has the potential to reduce, even eliminate, the need for foreign oil . . . and offers a long-term solution to energy price volatility by allowing Air Force fuel needs to be filled through domestic production."[1] Noting that the Air Force is the largest consumer of energy in the Department of Defense (DoD), the report outlined a strategy for reducing military dependency on foreign energy.[2] The Pentagon's commitment to develop petroleum alternatives for the armed forces, which grew out of a task force Secretary of Defense Donald Rumsfeld convened during the Bush administration,[3] has continued under the Obama administration.

Driven by both national security and budget concerns, the DoD has actively been pursuing energy efficiency and clean energy initiatives throughout the armed forces. This includes Navy and Air Force goals to replace half their consumption of petroleum-based fuels that power their aircraft and vessels with alternative fuels over the next decade. Towards this end, both services have nearly completed demonstrations using 50/50 blends of biofuel and fossil-based fuels in their fleets. In addition, the Navy has joined with the Departments of Energy (DOE) and Agriculture (USDA), in partnership with the private sector, to provide $510 million over a three-year period to catalyze the growth of a competitive advanced biofuels industry, compatible with the military's infrastructure.[4]

Through these programs, the Pentagon hopes to assure the military services' access to stable, cost-competitive fuel supplies to support their missions, which would be less subject to interruption by geopolitical instability and fuel price volatility.[5] Petroleum-based fuel dependency, the Air Force argues, not only threatens America's economic security, "it also threatens USAF mission accomplishment."[6] U.S. Navy Secretary Ray Mabus goes further, arguing that fossil fuel dependence endangers sailor and marines during the time of war, urging that the solution "is the utilization of alternative fuels."[7]

Pentagon leaders also point to the impact of rising costs and volatility of petroleum prices on military budgets. The Air Force spends $8 billion on petroleum and electricity every year, mostly on fuel for its aircraft, consuming a large portion of its budget.[8] A Pew study estimates that a mid-2011 increase in a gallon of oil, if carried forward, could raise the Air Force's energy costs by $2.3 billion.[9] Similarly, Secretary Mabus claims that every dollar increase for a barrel of oil adds $30 million annually to the Navy's budget.[10] The Navy accounts for a third of all federal government fossil-fuel consumption, and little of "the fuel that we are using in the fleet today or using on our bases today comes from the United States," he adds.[11]

DoD's Role in Advanced Biofuels

The military's advanced biofuels initiative has come at a critical juncture for the U.S. biofuels industry. The Environmental Entrepreneurs (E2) *Advanced Biofuel Market*

Report 2012 shows that policies such as the Renewable Fuel Standards (RFS2), California's Low Carbon Fuel Standard (LCFS), federal funding programs, and tax incentives, have helped the advanced biofuels industry grow. The advanced biofuel market has been expanding and advanced biofuel companies continue to develop both technologically and commercially.[12]

Nevertheless, the industry continues to face major challenges in the ability to finance plants to reach commercial scale production, as well as maintaining marketplace certainty. Building advanced biofuel refineries requires large outlays of capital at a time when capital availability is limited. Advanced biofuel producers also view marketplace stability as crucial for encouraging private capital investment into expanding advanced biofuels production.

E2 recognizes that government policies and funding programs can help create that stability and foster an environment attractive to private investment. The combination of a large, stable market demand, investments, and support for innovation enabled by the DoD and other federal programs can help attract greater private investments and reduce advanced biofuels costs as manufacturers move down the learning curve and benefit from economies of scale as the industry expands.[13] The military's advanced biofuels program therefore could play an instrumental role in enabling the growth of a large, commercially viable and competitive advanced biofuels sector while providing significant benefits for national security, the environment, and our economy.

This is not a new role for the military. The DoD has long supported the research, development, demonstration and early commercialization of—and often provided early markets for—new technologies with significant military and civilian applications, which eventually made their way into widespread commercial use with major economic and social benefits, most notably the computer, Internet, semiconductors, microprocessors, radar, and jet engines, among many others.

Congressional Concerns

Some in Congress have raised concerns about the costs of this program, asking why the military is spending millions on developing the new fuel markets at a time it is buying less equipment and considering salary cuts.[14] As biofuels proponents in the military argue, this is a small price compared to the benefits of reducing the military's dependency on Middle Eastern oil, with all its volatilities.[15]

Other lawmakers have questioned the seeming exorbitant costs of producing biofuels—citing the $26-per-gallon biofuel-petroleum blend fueling the Navy's "Great Green Fleet" demonstration.[16] However, this reflects a misunderstanding of the economics of the innovation and commercialization process. The biofuels used in the military's demonstrations of biofuels are produced in relatively small, experimental quantities. They primarily are meant to test the viability and compatibility of the new fuels with the military services' equipment and

infrastructure. Comparing costs of biofuels produced solely for demonstration purposes with petroleum-based fuels sold in commodity markets is essentially an apple and oranges comparison.

In any event, the ultimate goal of the military alternative fuels program is to assist in the growth of a commercially viable advanced biofuels industry, capable of-providing alternatives fuels that can cost-competitively substitute for petroleum-based fuels on a large-scale. As Navy Secretary Mabus argues, in response to the program's critics, every time the Navy has changed energy sources, "there have been doubters. There have been people who have said, you are abandoning one proven and certain technology for an unproven more expensive, less sure one. And every time, they have been wrong."[17]

Assessing the Benefits

Notwithstanding the Congressional concerns, the potential economic benefits of advanced biofuels for both the military and the larger civilian economy are still not well understood. The study summarized in this report is an important effort towards filling this gap. In particular, the study conducts a first order analysis and bounding exercise to assess the potential economic impacts and benefits of the military's advanced biofuel initiatives. As noted below and explained in the technical appendix below, our methodology entails:

- Employing a simple spreadsheet model of the biofuels industry to estimate the direct costs and jobs associated with the value chain sectors that would be involved in producing biofuels to meet the military's fuels targets;
- Applying appropriate economic multipliers to these values to estimate the economic ripple effect of this buildup on downstream industrial sectors and the economy as a whole;
- Specifying both high and low bounds for these impacts, reflecting the uncertainties and wide variance in the costs associated with a range of potential technology pathways for producing biofuels for the military program.

While there's a sizable literature evaluating the economic aspects of conventional biofuels, a smaller but growing number of studies have only appeared in recent years on the economic costs, impacts and opportunities of advanced biofuels.[18] Because it is so new, there has not yet been a systematic, empirically based analysis of the proposed military advanced biofuels program.

Although limited data and time enables only a preliminary look at the economics of the military biofuels program, we hope the study will help inform the current debate in and around Congress about the economic viability and benefits of the program, and which policies might be needed to strengthen it. By the same token, the study could provide a useful foundation for further research and a larger, more comprehensive study of the program and policy options, at a later date.

STUDY APPROACH

The primary objective of our study is to assess the economic consequences of the Pentagon's investment and purchase of advanced biofuels, to meet its stated goal of replacing the petroleum-based fuels used by the Air Force and Navy in their aircraft and marine fleets with alternative fuels by 2020. In order to make this assessment, we developed the *Military Biofuels Economic Impact Analysis* (MBEIA) model—a simple spreadsheet model of the primary cost structure components that comprise the advanced biofuels value-chain. Drawing on the findings of this analysis, and an extensive review of the literature, we examine the following questions:

1. *What are the economic impacts of the military investment in producing and purchasing advanced biofuel products to meet its targets?* This includes the potential impacts on *output, employment* and *value-added* over the time period for reaching the military's targets at the national level.
2. *What are the regional impacts resulting from this program?* Although a regional and local geographical breakdown of the impacts evaluated at the national level is beyond the scope of our study, we applied the MBEIA model and drew upon other studies to provide insights in examining this question.

It is important to note that this study represents only a fraction of the benefits of a successful advanced biofuel endeavor. As the advanced biofuel industry emerges, the military will only be one customer among others such as commercial aviation. Our study does not seek to capture industry wide results, which are difficult to assess at this time. Instead, it attempts to measure the tangible benefits of a specific military commercialization initiative that is currently underway.

Earlier Studies

Although there is a small but growing literature evaluating advanced biofuels production—including the E2's 2012 market study—little of this work is focused on the kind of advanced biofuels, and the technologies and feedstock employed in making them, with the characteristics the military has specified for meeting its alternative fuels goals. As discussed below (see also Box A), the military program calls for what is termed "drop-in" fuels that can be blended with petroleum-based fuels and used in existing aircraft and ships without the need to modify equipment. There is significantly more information available in the literature about cellulosic and biodiesel fuels than can be found about drop-in type fuels, such as renewable diesel, among others.[19]

Nevertheless, we still were able to draw upon several studies in the broader literature for data, insights, and analytical approaches that could be applied to our own inquiry. For example, we reviewed several detailed, engineering-economic analyses of advanced biofuel production facilities and processes, to compare different conversion technologies and pathways, evaluate feedstock varieties, costs and availability, and provide the basis for evaluating their economic potential (and, in some instances, their environmental impacts).[20] A few of these analyzed and

compared different conversion processes and feedstock that produce drop-in type fuels, to identify data points we could use in our model. We also were able to draw upon empirical data for a handful of currently operating (or soon to be operating) U.S. plants from the E2 market report and other sources.

Several different economic models (mainly input-output models such as IMPLAN and RIMS II) have been applied in these studies. The approach we adopted, however, is more like that used by *bio-era*, a bio-economics research organization, in its 2009 study, *U.S. Economic Impact of Advanced Biofuels Production: Perspectives to 2030. Bio-era* conducted a "meta-analysis" of two-dozen studies to provide the foundation for the assumptions and methodology used in the economic model it employed to examine the economic impacts of advanced biofuels production if scaled up to meet the Renewable Fuels Standards (RFS2) requirements for advanced biofuels by 2030.

Like *bio-era*, we drew upon a number of studies (including *bio-era's*) to establish the various data assumptions used to characterize the different value-chain costs components, such as conversion technologies and feedstock supplies, used in the MBEIA model. We similarly modeled the potential economic impacts from a scaling up of advanced biofuel production, in our case, to meet projected demand created by the military's alternative fuels targets. At the same time, we differ from *bio-era* in the kinds of advanced biofuels that are examined. *Bio-era's* study was based on projections of expansion in the production of cellulosic ethanol and biodiesel fuels, while we are focused on advanced biofuels that meet the criteria of "drop-in" fuels.

The Military Biofuels Program

The first analytical step is to characterize the military biofuels program. This includes specifying the targets and goals and proposed policies for supporting the development and use of alternative fuels by the services, and then specifying the criteria and characteristics that the military requires to meet its fuel requirements.

The U.S. armed services' commitments to reduce petroleum use and develop biofuel substitutes were stated in the DoD's *Operational Energy Strategy* (OES) released in March 2012: [21]

- The Air Force plans to cost-competitively acquire 50 percent of its domestic aviation fuel requirement via an alternative fuel source by 2016;
- The Navy plans to use alternative sources for half of all energy consumption afloat by 2020.

According to the OES report, meeting the Air Force's goal would require 387 million gallons per year (MGY) of new advanced biofuels capacity by 2016.[22] Meeting the Navy's (and Marine's) goal would require at least another 300 MGY of new capacity by 2020.

We did not include the Army in our study, even though Pew reports that it also is seeking to adopt alternative fuels to power its vehicle fleet and meet the President's Executive Order 13423 goal of increasing the use of non-petroleum fuels by ten percent per year in non-tactical vehicles.[23] While the Army also has been certifying its equipment, it has not made a comparable commitment to specific goals or policies for procurement or widespread adoption of alternative fuels [24]

In addition to the fuel targets, the Navy, DOE and USDA plan to provide $510 million over three years to support the military's alternative fuels program. The Navy and Air Force tests to demonstrate the viability of advanced biofuels in their equipment and systems have been important steps towards meeting the military's fuels goals. For example, the Air Force has successfully flown most of its major aircraft on 50/50 blends of biofuel and JP-8 jet fuel, such as the A-10 Thunderbolt, C-17 Globemaster, F-15 Eagle and F-22 Raptor.[25] By mid-2011, 99 percent of the Air Force's fleet was certified to fly biofuel blends, and experts expect demonstrations to be completed by the end of 2012. [26]

Similarly, the Navy has conducted numerous successful demonstrations of biofuel used in its aircraft,[27] boats and riverine craft.[28] In July 2012, the USS Nimitz took on more than 900,000 of 50-50 biofuel in preparation for the Navy's Great Green Fleet demonstration for participation in Rim of the Pacific (RIMPAC) 2012, the world's largest international maritime exercise.[29]

Military Alternative Fuels Criteria

The fuel and equipment demonstrations have played a vital role in enabling the services to meet their alternative fuels goals. The military has specified several criteria for alternative fuels to be considered suitable for use:[30]

- *Drop-in capability*. As noted, alternative fuels must be *"drop-in"* substitutes—with comparable energy and performance characteristics that enable them to blend with or replace the petroleum-fuels used by the military in its domestic fleets of aircraft and ships.[31] The alternative fuels must not require major engine modifications or prevent the use of petroleum-based fuels such as JP-8, JP-5 and F-76 fuels.[32] They also must be compatible with other aircraft fuel system materials including various metals, epoxy-type coatings and elastomeric seals.[33]
- *Feedstock supply and diversity*. There must be suitable and diverse supplies of feedstock available that the fuels can be made from.[34] The Air Force is reported to be "feedstock agnostic," as long as the final product meets its performance specifications.[35] Military officials also emphasize that the feedstock must come from non-food sources and that the fuel not increase the carbon footprint.[36]
- *Scalability*. The alternative fuels must be able to be produced at a big enough scale and commercially available, with production capacity scalable up to the military's targets.

- *Distribution system compatibility*. Qualified biofuels must be able to use the existing fuel distribution systems, consisting of railroads, tanker trucks, barges and pipelines, the military currently uses to transport its petroleum-based fuels, which, in addition, would help reduce costs.[37]
- *Cost-competiveness*. The alternative fuels must be price competitive with the petroleum fuels they replace.

The evidence indicates that these criteria can be met by advanced biofuel alternatives. As already noted, the Navy and Air Force are near the end of a testing period during which they have been successfully demonstrating that advanced biofuel alternatives are compatible with petroleum-based fuels, and can be used in existing military hardware. The military test fuels have been made from a variety of feedstock, including waste oil, animal fats, woody residues, and oilseed crops such as camelina that can be grown throughout the country.[38]

A relatively small but growing number of existing, commercial-scale renewable gasoline or renewable diesel facilities employ conversion technologies and feedstock suitable for making drop-in compatible biofuels. Box A provides a short description of several technologies and feedstock options that can produce drop-in fuels, which would need to be employed on a large scale to meet the Air Force and Navy alternative fuels goals.

MODEL ASSUMPTIONS AND CALCULATIONS

The wide variety of feedstock and conversion technologies which can be used in making biofuels to meet the military requirements, as described in Box A—and the diversity of demonstration plants and smaller number of commercially operating plants capable of producing drop-in fuels—creates challenges for the modeling process. The different cost characteristics for potential conversion processes and feedstock make it difficult to choose appropriate values that characterize the principal components of the MBEIA model.

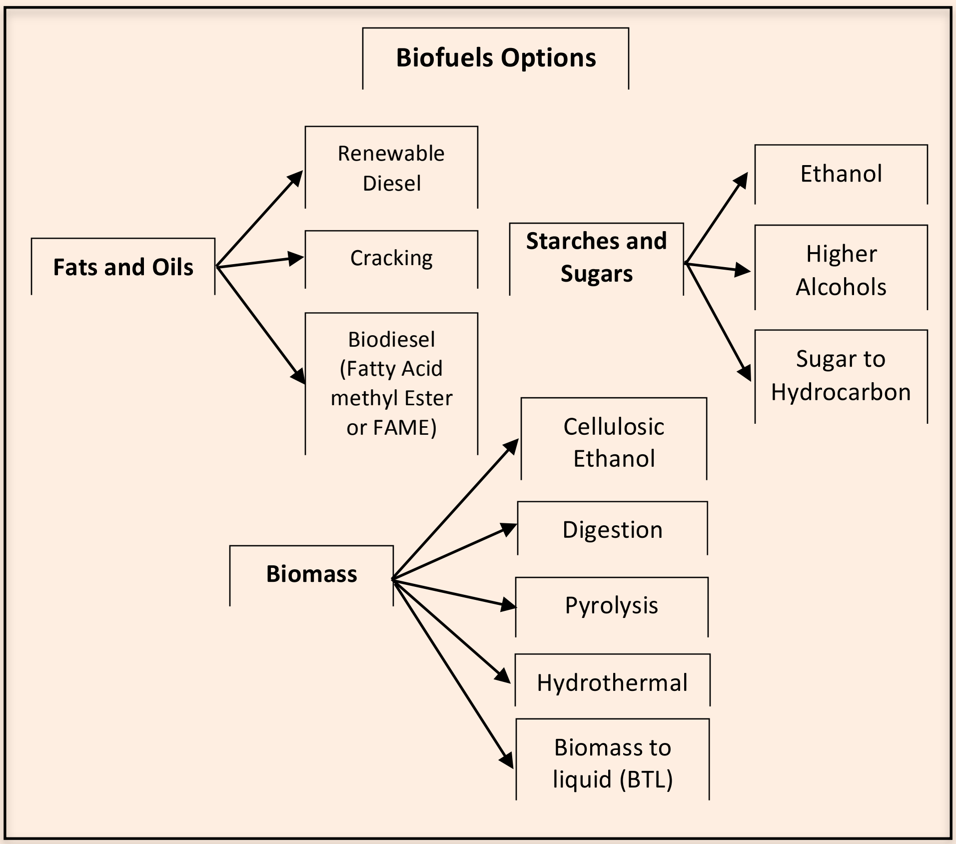
To address this uncertainty, we specify somewhat wide ranges for key cost parameters for the value-chain sectors (e.g., feedstock costs, operating costs), which yields a range—both high and low estimates—of potential economic impacts we calculated would result from the military biofuels program. That is, we set large high and low bounds that we believe would likely cover most of the possible costs and impacts that might result from diverse drop-in fuels feedstock and conversion pathways. While some emerging pathways (e.g., alcohols and algae to drop-in fuels) are not included in our study for lack of adequate data, we seek to set the range of possibilities wide enough to capture their possible effects as well. However, some inaccuracy would be implicit in any approach, reflecting the early stage of this industry.

Box A

Military Drop-In Biofuels

Drop-in biofuels are hydrocarbon fuels substantially similar to gasoline, diesel, or jet fuels, with the ability to be used in existing engines and infrastructure with minimal compatibility issues.[39] There are multiple feedstock and technology pathways to produce drop-in fuels, most of which build on or extend existing biofuel pathways. Figure 1 shows a range of possible feedstock and technology pathways for producing biofuels. The starch and sugars pathways are the conventional or first generation processes for producing ethanol and other fuels. The fats and oils and biomass pathways include second and third generation (or advanced biofuels) processes for producing other kinds of biofuels, including drop-in biofuels.

Figure 1: Summary of Biofuel Options



Source: UC Davis and UC California, *California Renewable Diesel Multimedia Evaluation, Tier I Report.* Prepared for California Environmental Protection Agency, Multimedia Working Group, December 2010: figure 1.1, p. 16.

The Department of Energy Alternative Fuels Data Center (AFDC) has identified a variety of feedstock that can be used to produce drop-in fuels, including animal and plant oils, crop residues, woody biomass, dedicated energy crops and algae:

- Animal fats (tallow) and grease (including yellow grease from waste vegetable oils) are recycled from restaurants and meat processing plants;

- Plant oils are extracted by crushing or chemically treating oil seed plants (such as rapeseed, camelina, canola, and jatropha);
- Plant-based biomass comes from cultivating non-food crops, agricultural residues and woody residues are harvested from forests or collected from wood products and paper mills.

There also are a variety of potential conversion technology pathways to produce drop-in fuels, many of which are in research and development phase with pilot- and demonstration-scale plants under construction. These include upgrading alcohols to hydrocarbons; catalytic conversion or fermentation of sugars to hydrocarbons; hydrotreating algal oils; upgrading of syngas (CO and H_2) from gasification;[40] pyrolysis or liquefaction of biomass to bio-oil with hydroprocessing; and hydrogenation-derived renewable diesel (HDRD) fuels.[41]

In our study, most of the data available on drop-in biofuels comes from studies of—and a few existing facilities that use—one of the last three pathways.

- The thermochemical conversion process involves heat and pressure-based chemical reactions to produce syngas, which subsequently can be converted by a Fischer-Tropsch (F-T) reactor to diesel and naptha.[42]
- Pyrolysis involves thermal decomposition of biomass material in the absence of oxygen or liquefaction of biomass to bio-oil,[43] which is then hydrotreated to a conventional hydrocarbon fuel by removing oxygen. Hydrotreating is similar to the process to remove nitrogen and sulfur from hydrocarbons, a common and well-established refinery process. Hence, drop-in biofuel production can be done in retrofitted petroleum refineries,[44] lowering the costs of constructing a production facility, relative to building a new, stand-alone plant.
- Hydrogenation-derived renewable diesel, also known as green diesel or second-generation biodiesel, is produced from fats (animal tallow, waste or brown trap grease) or vegetable oils (soybean, palm, canola, or rapeseed oil; vegetable oil waste) refined by a hydrotreating process.[45] Renewable diesel can also be made in existing biodiesel plants by bolting on hydrogenation and isomerization units.[46]

The Navy and Air Force tests, in fact, reflect the diversity of alternative feedstock and conversion technologies that the military has been exploring for making alternative fuels. For example, the Air Force's alternative fuels certification office is preparing test fuels made primarily from plant oils and animal fats, part of a family of fuels called "hydro-treatable renewable jet" or HRJ fuels. Many of the Air Force test flights have used a 50/50 biofuel-JP-8 jet fuel derived from camelina, a nonfood rotation oilseed crop similar to soybean and mustard.[47]

The U.S. Navy's demonstration of a Green Strike Group is purchasing biofuel made from non-food grade animal fat and grease (used cooking oil and yellow grease) from the Louisiana-based Dynamic Fuels, LLC, a joint venture of Tyson Foods Inc. and Syntroleum Corporation and an algae-based biofuel produced by Solazyme.[48] Meanwhile, the military departments and DARPA are each making significant science and technology R&D investments across a spectrum of power and energy technologies, including new biofuel alternatives.[49]

For example, the costs of constructing, supplying feedstock and operating biofuel conversion plants vary greatly across the commercially viable—or soon-to-be commercially viable—technologies and feedstock available. The capital costs of a thermochemical F-T plant that converts agricultural or woody residue into renewable diesel, tend to be somewhat higher than the costs of building a new hydrogenation-hydrotreatment plant that converts animal fat or oilseeds (such as camelina) into a "drop-in" jet fuel—although if the latter process is incorporated into a retrofitted refinery, its capital costs could be significantly lower.

Our study however is not concerned with comparing the economics of different conversion technologies and feedstock options. Like the Air Force, we are "agnostic" regarding the mix of biofuel plants and their specific conversion technologies and feedstock preferences that might emerge to meet the military's fuel requirements over the remainder of the decade. In any case, it is not possible to know how this growth might actually play out over time. The drop-in biofuels production is still a nascent industry, and it is not possible to predict, at this time, which feedstock and conversion pathways might become the most cost competitive and predominant sources of drop-in biofuels used by the military.

Nevertheless, we needed to choose values that allow us to approximate a reasonably realistic set of costs associated with the value-chain sectors, which can be used in the MBEIA model. The approach and methodology we applied to develop the model, and the data and assumptions we used to (i) calculate the expenditures associated with the main sectors in the biofuels value-chain, and (ii) the economic impacts based on these expenditures resulting from the military biofuels program, are elaborated in some depth in the technical appendix. The results of these calculations are summarized below.

Box B

A Note on Sustainability

Next generation biofuels can provide significant environmental and social benefits if developed with caution and foresight. Potentially, they avoid the environmental, economic and national security liabilities associated with petroleum. But they also pose serious environmental risks if scaled up without foresight. As the Department of Defense adopts advanced biofuels, it must take stock of the possible risk to land, water, air, and food. This will ensure that strategically meaningful volumes of alternative fuel can endure over the long term. Specific risks include greenhouse gas emissions, soil, water and air quality concerns.

Fortunately, these challenges are surmountable if DoD carefully screens its fuel options. The solicitation process can mitigate risk by awarding credit to projects that perform best. DoD can also acknowledge certification under a credible, third party certification system such as the Roundtable on Sustainable Biofuels (RSB). RSB certification spans the entire fuel lifecycle, allowing DoD to purchase alternative fuels with confidence that they will sustain themselves environmentally and politically.

Military Biofuels Processing Capacity

To meet the combined Navy and Air Force biofuel targets we estimate a total capacity of *770 MGY* of renewable diesel drop-in fuels would need to be built by 2020. The Air Force set a target of *387 MGY* new production capacity by 2016 and the Navy seeks 300 MGY of new biofuels capacity by 2020, for a combined *687 MGY* of new capacity by 2020 for both services. However, if we assume a plant capacity utilization rate of *90 percent*,[50] the total domestic fuel capacity that actually would be needed to meet to the Air Force goals is approximately 430 MGY of plant capacity by 2016, and another 340 MGY by 2020 to meet the Navy goals.

The first step in developing the MBEIA model was to specify a reasonable scenario of growth in processing capacity that can produce drop-in grade fuels meet military requirements, which is shown in table 1. As explained in the technical appendix, we base our scenario on a review of the literature and empirical evidence about the growth of existing biofuels capacity presented in the E2 market report, and therefore a good first approximation for meeting the Air Force and Navy targets.

In this scenario, we assume plant sizes of 10 MGY, 20 MGY, 50 MGY and 75 MGY capacity are built to meet the new demand over the 2013-2014 period. We also assume that there already is in place, or currently being built, some production capacity that can provide "drop-in" fuels that meet the military fuel targets (see technical appendix).

Table 1—Drop-In Capable Biofuels Processing Facilities

Year	Existing or Planned Capacity		New Installed Capacity (Number of New Plants)				Total New Capacity		Total Operating Capacity	
	No. Plants	Total Capacity (MGY)	10 MGY	20 MGY	50 MGY	75 MGY	No. New Plants	New Capacity (MGY)	No. Plants	Total Capacity (MGY)
2013	2	85	0	0	0	0	0	0	**2**	**85**
2014	1	35	0	0	0	0	0	0	**3**	**120**
2015			2	2	0	0	4	60	**7**	**180**
2016			2	4	3	0	9	250	**16**	**430**
2017			0	2	1	0	3	90	**19**	**520**
2018			0	0	2	0	2	100	**21**	**620**
2019			0	0	0	1	1	75	**22**	**695**
2020			0	0	0	1	1	75	**23**	**770**
TOTAL	**3**	**120**	**4**	**8**	**6**	**2**	**20**	**650**	**23**	**770**

That is, we begin the ramp-up period for providing new capacity with approximately *120 MGY* in total *existing* or *already planned capacity*—a total of 85 MGY capacity already in place and 35 MGY in new capacity expected to be available by 2014. However, although we know the feedstock and conversion technologies of the initial existing or planned facilities in our scenario, we do not try to predict the

future mix of production plants and feedstock used. In any event, a total of *650 MGY* of additional capacity would be needed to meet the military's goals.

Advanced Biofuels Value-Chain

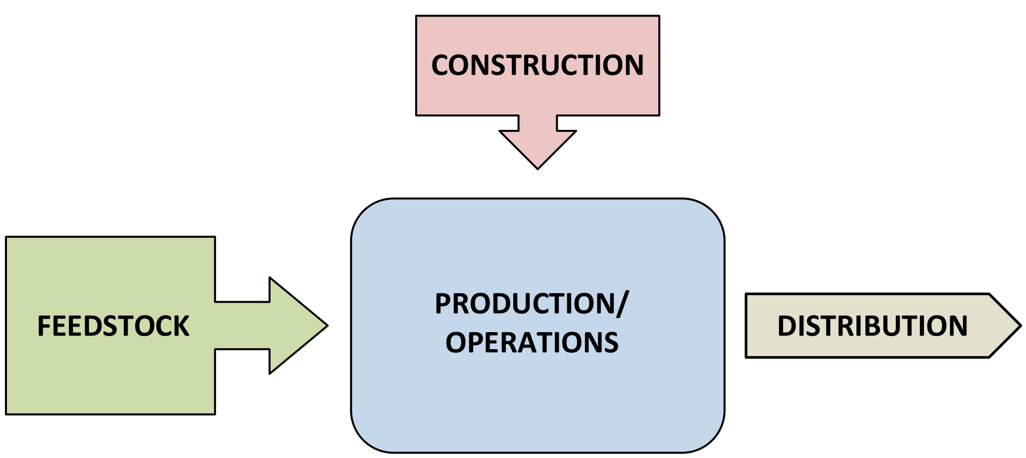
Figure 2 is a simplified schematic of the advanced biofuels value-chain, which can be applied regardless of the type of biofuel being examined. Although there are other important raw materials used in the production of biofuels, the most important is the feedstock converted in a production facility to produce the fuels, which are then distributed to final end-use locations (or storage facilities that can be tapped into for later use).

Each value-chain component actually consists of many individual parts. Detailed engineering-economic studies, in fact, often identify and estimate values for these parts in estimating overall costs. Our primary concern is with the costs associated with each component taken as a whole. As described in the technical appendix, our assumptions about these values are derived from a review of relevant literature.

In short, in order calculate the economic impacts associated with a scale-up of advanced biofuels production, we first estimate the costs over time of each value-chain component, which includes:

1) *Construction* of the production plants used to convert the feedstock to fuels and various co-products (e.g., naptha)
2) *Feedstock* production, purchase and transport to the plant
3) *Operation* of the production plants (not including feedstock costs), and
4) *Distribution* of the new fuels to end-users.

Figure 2: Advanced Biofuels Value-Chain Schematic



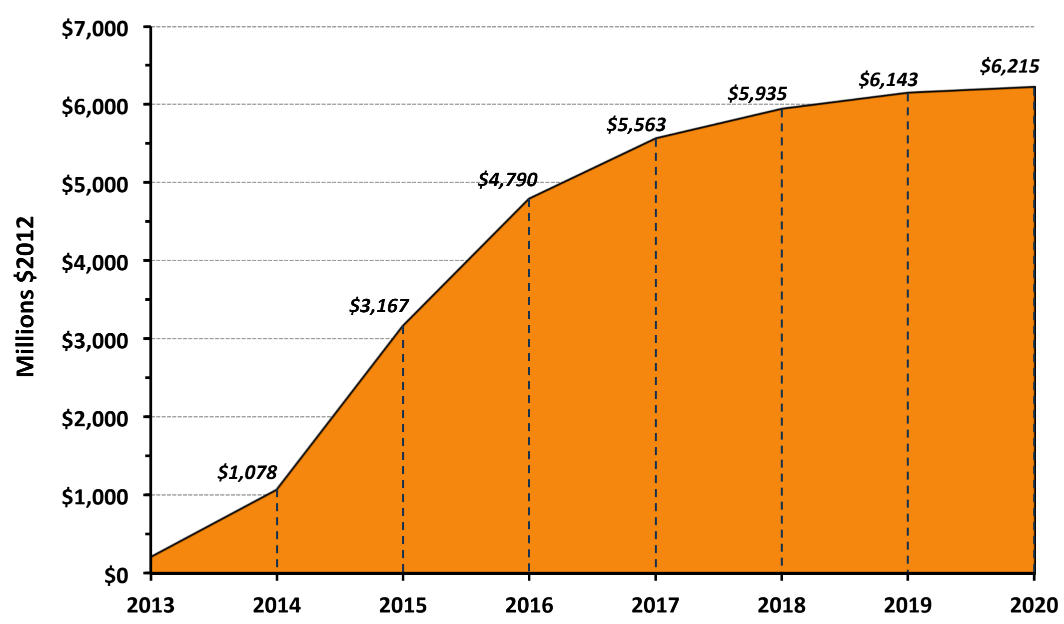
We then estimate potential jobs created associated with each of these components. The cost and job estimates are then added together to provide projections for each year examined in the study (in our case from 2013 to 2020) and the total cumulative

quantities over this period. Finally, we apply appropriate multipliers to estimate the economic impacts on other industrial sectors and the economy as a whole.

Construction Expenditures

The technical appendix describes the statistical and scaling methodology and assumptions we use to determine a plant size-construction cost relationship in the MBEIA model. Its purpose is to produce reasonable first-order approximations of construction costs across the spectrum of possible plant sizes and production processes. The results of the model analysis based on these assumptions are summarized in figure 3. It tracks the yearly growth of total direct construction expenditures on new biofuel plant capacity through the year 2020. Therefore, over the 8-year period, 2013-2020, these expenditures, resulting from building a projected total of 685 MGY of new biofuel capacity (including 35 MGY already planned and expected to begin construction in 2013) to meet the military fuel targets could total as much as *$6.2 billion*, or average annual expenditures of approximately *$777 million.*

Figure 3—Construction Costs for New Military Biofuel Capacity



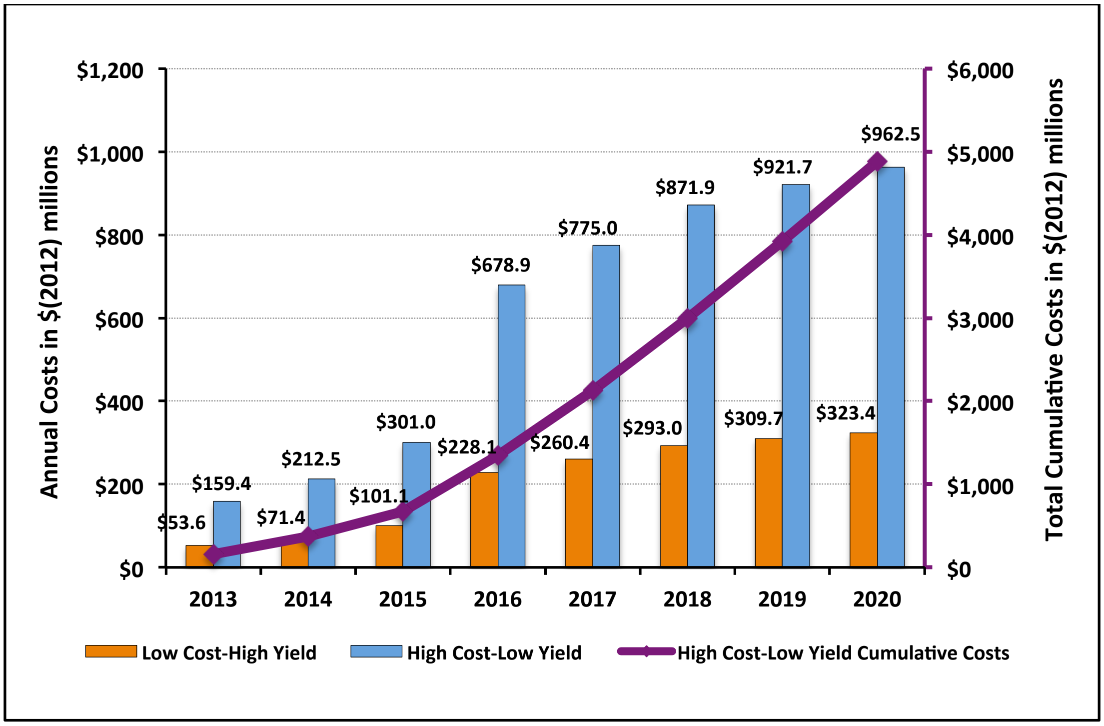
Feedstock Expenditures

The results of the MBEIA model estimates of feedstock costs are summarized in figure 4. As described in the technical appendix, we specify a wide range of costs and yield to encompass the diversity of feedstock that might be used in drop-in biofuels production, which subsequently are reflected in the wide range (high and

low estimates) of total feedstock costs estimated by the MBEIA model, illustrated in figure 4.

In the low-cost high yield scenario, yearly feedstock costs would grow to *$323 million* per year by 2020, for a total cumulative expenditure on feedstock production of *$1.6 billion* between 2013-2020, or average yearly spending of $205 million over this 8-year period. In the high-cost low yield scenario, annual feedstock expenditures would increase to about *$963 million* per year by 2020, for a cumulative total of *$4.9 billion* (the purple marked line chart in figure 4), or average annual spending of *$610 million*, over the 2013-2020 period.

Figure 4—Feedstock Expenditures for Military Biofuel Production



Operating Costs

As in the case of the construction and feedstock costs, there is a wide range of possible values that vary greatly across the principal types of conversion technologies and the diverse kinds of biomass used in producing the drop-in biofuels for the military. A review of the literature and empirical data shows a very wide range in the operating costs per gallon of fuel produced, depending on the conversion processes and feedstock employed in the various biofuel plants examined.

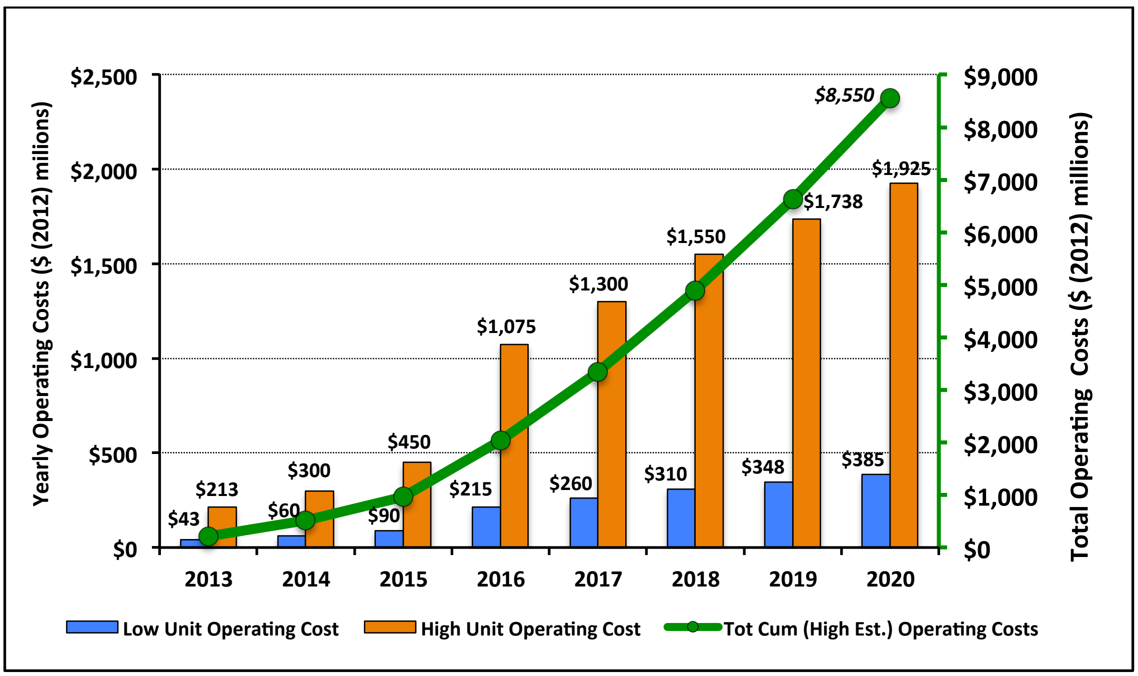
As with feedstock costs and estimates, and discussed in the technical appendix, we chose a wide range unit operating costs, to account for the large range of operating costs associated with large diversity of conversion technologies that can be used to

produce drop-in biofuels. These in turn are used to calculate a high and low estimate of overall operations expenditures resulting from the ramp up of advanced biofuels capacity to meet the military alternative fuels targets by 2020.

Figure 5 summarizes the MBEIA's estimates of these expenditures. It shows both the yearly expenditures and cumulative total for the high end operating cost scenario. We see that in the low cost scenario, operating expenditures would only grow to *$385 million* per year by 2020, and in the high operating cost scenario the yearly costs would grow to *$1.9 billion*—five times as great as the low-end case—by 2020, when the military biofuel production target would be met.

In the high operating cost scenario, the yearly operating expenditures would rise. Overall, in the high-cost case, a *cumulative* total of *$8.6 billion* (green marked line in figure 5), or an annual average of *$1.1 billion* per year, would be spent for operating drop-in biofuel plants—compared a cumulative total of *$1.7 billion,* or average annual spending of *$214 million,* in the low-cost case—to meet the military's demand for biofuels over the 8-year period between 2012-2020. The very large divergence between the high- and low-end expenditures reflect the uncertainty about the types of plants, conversion technologies and feedstock of the facilities built to meet the military drop-in biofuels targets by 2020.

Figure 5—Operating Expenditures for Military Biofuel Production



Distribution Costs

The military already has a fuel distribution system in place consisting of railroads, tankers, trucks, barges and pipelines. The Air Force study has noted that the costs could be prohibitive if the new fuels made for its missions would require the

establishment of a new distribution system, which might be necessary to transport ethanol on a large scale.[51] On the other hand, the National Academy's study on biofuels states that "drop-in" fuels would be able to use the existing petroleum infrastructure for delivery of the fuels to the final customer.[52]

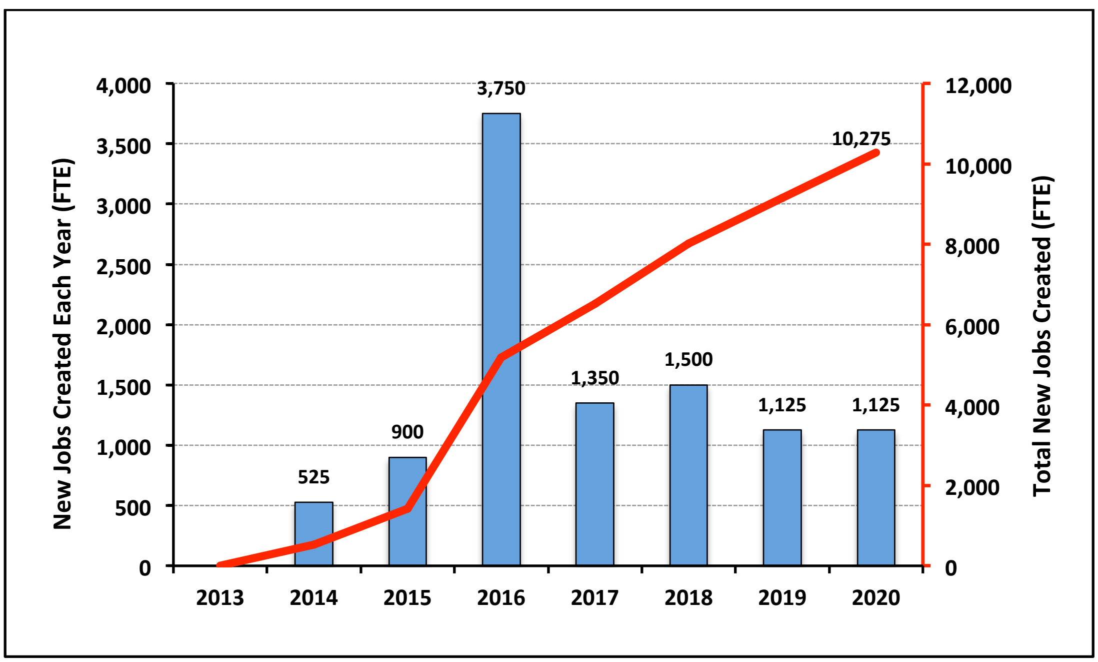
Using the NAS distribution cost range in the MBEIA model, we estimate that by 2020 total yearly distributions expenditures would rise to *$14 million* in the low-cost case and to *$35 million* per year in the high-cost case. Total cumulative expenditures would be *$62 million* and *$154 million*, respectively.

Employment Estimates

To estimate the job impacts resulting from the military biofuels program, we use an approach similar to that used in the *bio-era* study estimating construction, feedstock production and operations employment. See the *technical appendix* for the methodology we use to estimate the main employment parameters for each value-chain sector (jobs per MGY of capacity or other relevant variable) and the calculations we use to estimate the direct employment associated with each sector.

Figure 6 illustrates the number of jobs that would be created in the construction of new plants for producing biofuels to meet the military targets. It shows that while the number of construction jobs created each year varies with the number of new construction plants being built for a particular year (bar chart), a total of *10,275 jobs* would be created by building the biofuel production plants required to meet the military targets over the 8-year period of 2013-2020 (line chart).

Figure 6—Total Jobs Created in Construction of Military Biofuels Plants



Construction jobs are temporary and last only for the duration of a project. Feedstock jobs are permanent jobs. They include jobs created in the feedstock production, collection, harvesting, preparation, transportation and storage, and increase yearly as feedstock demand grows. Similarly, operating jobs and distribution jobs are permanent jobs associated with the running of the biofuel production facilities and the transport and distribution of the biofuels to their end-users, respectively, and increase as the number and capacity of biofuel plants grows in response to rising military demand.

The estimated number of direct jobs created and supported for *each component* in the value chain, and in total, from 2013 to 2020, is summarized in table 5. The first column shows the total number of new permanent jobs that we estimate would created by 2020 for each value-chain sector and in total. Since the number of employees involved with feedstock, operations, distribution each year grows as capacity expands, the 2020 jobs number represents the total number of unique *new* jobs created over the 8-year build-up to meet the military targets. As table 5 shows, a total of over *4,000* to *7,000* new (permanent) jobs would be created by the feedstock production, operations and distribution parts of the value-chain in supplying biofuels for the military by 2020.

Table 5—Number of Direct Biofuels Industry Jobs Created and Supported

Value-Chain Components	Jobs Created by 2020	Cumulative Job-Years Supported 2013-2020	Average Number of Jobs Supported Annually
Feedstock (High Estimate)	4,607	24,320	3,040
Feedstock (Low Estimate)	2,764	14,592	1,824
Operations Jobs	1,232	5,472	684
Distribution Jobs	52	229	29
Construction Jobs Created	—	10,275	1,284
Total Jobs (High Estimates)	**7,015**	**40,296**	**5,037**
Total Jobs (Low Estimates)	**4,048**	**30,568**	**3,821**

Feedstock production would create the largest number of jobs. Because of the capital-intensive nature of biofuels production, like most other industries in the chemical manufacturing sector, plant operations would create and support fewer jobs, and distribution would support a much smaller number of jobs still. Adding these numbers to construction jobs created, which are unique, albeit temporary jobs, we see that as many as between *14,000* to over *17,000* new jobs would be created over this period by the military biofuels project by 2020. If the military

keeps its demand for drop-in fuels at the same level, only the feedstock and operations, and distribution parts of the value-chain would continue to support jobs, at the 2020 level.

Table 5 also shows the total *cumulative* number of job-years that would be supported over the 2013-2020 period (measured in job-years), and the *average* number of jobs supported each year during that period. The former is the sum of the number of jobs supported each year (which grows with capacity each year) over the 8-year period of the military biofuels capacity buildup.

As seen in the table, the MBEIA model estimates that a total cumulative number of *30,600* to *40,300 job-years* would be supported over for all parts (including construction) of the biofuels production value-chain. This translates to an average of approximately *3,800* to *5,000 jobs* supported each year. Of this cumulative total, a combined 20,300 to 30,000 job-years would be supported in the feedstock production, operations, and distribution sectors alone, or an average of about 2,500 to 3,750 jobs supported annually.

MEASURING ECONOMIC IMPACTS

The expenditure and jobs estimates above represent only the *direct* economic outputs that would be generated as a result of the military's purchase of drop-in biofuels to meet its fuel targets by 2020. To determine the full economic impact of the military biofuels program, we must also measure the ripple effect of new economic activity that would be stimulated by these expenditures and jobs.

Direct Economic Impacts

First, table 6 summarizes the direct economic output increases calculated above associated with the addition of 685 MGY of new advanced biofuels production capacity to meet the military biofuels targets over the 2013-2020 period. The direct employment impacts for each value-chain sector and for the advanced biofuels sector serving the military demand have been discussed above.

To meet the capacity increases needed to meet the military target, the advanced biofuels sector would produce from $9.6 billion to $19.8 billion in total output—for a yearly average of *$1.2 billion* to *$2.5 billion* in output—over the 2013-2020 period. This represents the total amount of dollars that flows into the economy resulting from the expenditures by all value-chain sectors, including construction, over this 8-year period. The average annual output represents the average amount of money pumped into the economy each year during this period.

Not including the expenditures from construction of the new capacity, which would be completed by 2020, the industry would directly add a total of $0.72 billion to $2.92 billion in new *yearly* output to the economy by 2020. This reflects the total that yearly expenditures would grow to by 2020, generated by the feedstock,

operations and distribution sectors in the drop value-chain, as production output in the industry expands each year to meet the military's fuel targets.

Table 6—Total Direct Biofuels Industry Output Increases

Value-Chain Sector Output ($ millions (2012))	Yearly Output by 2020	Cumulative Output 2013-2020	Average Annual Output 2013-2020
Feedstock (Low)	$323	$1,641	$205
Feedstock (High)	$963	$4,883	$610
Operations (Low)	$385	$1,710	$214
Operations (High)	$1,925	$8,550	$1,069
Distribution (Low)	$14	$62	$8
Distribution (High)	$35	$154	$19
Construction	—	$6.22	$0.78
Total Output (Low Estimates)	**$722**	**$9,627**	**$1,203**
Total Output (High Estimates)	**$2,922**	**$19,802**	**$2,475**

Indirect and Induced Economic Impacts

The spending on construction of new biofuels manufacturing plants, the purchases of goods and services required in the production of feedstock to supply the new plants, the operation of the plants to process the feedstock and produce biofuels, and finally, the distribution of the fuels to the military's final users, is money that flows into the economy, stimulating new spending by other businesses and workers in their supply chain. These businesses in turn purchase goods and services from businesses in other industries, which employ and provide compensation to other workers, who then spend their earnings on goods and services to meet their personal and household needs, and so on.

To measure these downstream economic impacts, as described in the technical appendix, we employed the BEA's RIMS II model[53] to determine appropriate multipliers for calculating both the *indirect* and *induced* economic impacts resulting from the growth of biofuel production and distribution capacity to meet the military's fuel demand over the 2013-2020 period.

- *Indirect impacts* refer to the change in economic activity resulting from subsequent rounds of production inputs purchased by industries affected by the projected military biofuel purchases.

- *Induced impacts* refer to changes in economic activity resulting from the changes in spending by workers whose earnings are affected by the military biofuel purchases.

Although the BEA's RIMS II multiplier approach to estimating economic impacts is a well-accepted methodology, the results need to be interpreted with a bit of caution. The indirect—and especially the induced—economic impacts calculated by this method, are only meant to provide rough estimates of the output and jobs that would be generated throughout the value-chain supporting a particular initiative—such as the military biofuels program—and the subsequent resulting economic activity that would ripple throughout the economy.

For both kinds of impacts, we calculated the economic outputs (revenues), jobs, and value added resulting from the economic activity stimulated by the military biofuels purchases. Value added is the gross output of an industry less its intermediate inputs, and represents the contribution of an industry or sector to the gross domestic product (GDP).

The RIMS II model provides two types of multipliers for calculating these impacts based on the direct economic outputs (expenditures or output and jobs)—Type I multipliers which can be used to calculate the indirect impacts and Type II multipliers which can be used to calculate the induced impacts. Each industry has its own set of multipliers for calculating these impacts based on changes in its output and jobs resulting from a final demand change, such as the military biofuel purchases. In the model, we used the multipliers for industries that are most similar to the sectors in the military biofuels value chain.

In the technical appendix we provide a detailed explanation of the methodology used to calculate the economic impacts and the multipliers applied to make these calculations (see table A-VI). Table 8 summarizes key findings of this analysis.

Table 8—Key Economic Impacts of the Military Biofuels Program

Economic Impacts	Yearly Impacts by 2020		Total Cumulative Impacts (2013-2020)		Ave. Yearly Impacts (2013-2020)	
	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate
Direct & Indirect Impacts (Type I)						
Output ($ billions)	$13.1	$18.3	$19.2	$43.3	$2.4	$5.4
Jobs (thousands)	*32.5*	*39.2*	*96.6*	*132.1*	*12.1*	*16.5*
Value Added ($ billions)	$6.4	$8.2	$8.6	$16.9	$1.1	$2.1
Direct, Indirect & Induced Impacts (Type II)						
Output ($ billions)	$21.5	$28.7	$30.0	$63.2	$3.8	$7.9
Jobs (thousands)	*53.9*	*64.3*	*160.5*	*215.4*	*20.1*	*26.9*
Value Added ($ billions)	$11.2	$14.1	$14.8	$28.3	$1.8	$3.5

As above, *yearly impacts by 2020* refer to the levels that the annual economic impacts resulting from the military biofuels capacity buildup would grow to by 2020. For example, we estimate that total direct and indirect output impacts in 2020 would be between *$13.1 billion* and *$18.3 billion*.

Total cumulative impacts (2013-2020) refer to the total economic impacts (output, jobs and value added) that would be generated over the 8-year period throughout the drop-in biofuel industry's direct and downstream value chain (direct and indirect) and throughout the economy (includes induced impact) as a result of this activity. *Average yearly impacts (2013-2020)* represent the average amount of economic impacts contributed to the economy each year during the 8-year period.

The values in table 8 do not distinguish the impacts resulting from plant construction (which is a temporary impact that fades out after all construction is completed) and the impacts from feedstock production, operations and distribution, which are permanent and hold at the value it reaches in 2020, after that year.

1. *The direct and indirect impacts (RIMS Type I)*

These include the sum of the direct impacts (output, jobs and value added) resulting from adding the new biofuels capacity from 2013 to 2020 to meet the military fuels targets, and the impacts resulting from successive rounds of purchases of intermediate goods produced by industries down the supplier chain, in response to the rising demand for fuels produced by the biofuels sector.

The table shows that total output would grow to *$13.1 billion* to *$18.3 billion* in output—and value added, to *$6.4 billion* to *$8.2 billion*—produced by all industries, by 2020, in response to the growth of drop-in fuel production to meet the military targets. This growth in output would be accompanied by the creation of *32,500* to *39,200* new jobs (temporary and permanent FTEs) by all industries by 2020.

Correspondingly, the total cumulative output (direct and indirect) produced by all industries over the 2013-2020 period would range from *$19.3 billion* to *$43.3 billion*, for an average annual output of *$2.4 billion* to *$5.4 billion*. Similarly, a cumulative total of *96,600* to *132,100* job-years would be supported over this period and a total cumulative increase of *$8.6 billion* to *$16.9 billion* in value added created over this period.

2. *Direct, indirect, and induced impacts (Type II)*.

Induced impacts are the product of successive rounds of spending in the economy (such as restaurants, supermarkets, clothing stores, online purchases, etc.), first by workers directly employed by the biofuels value chain sectors resulting from the increased demand from military biofuels purchases, and then by successive rounds

of purchase by workers down the supplier chain and in industries throughout the economy.

If the induced impacts are added to the direct and indirect impacts shown in table 8, by 2020, the military biofuels program would generate from *$21.5 billion* to *$28.7 billion* in output yearly—and *$11.2 billion* to *$14.1 billion* in value added yearly—produced by all industries. This growth in output would be accompanied by the creation of *53,900* to *64,300* new jobs (temporary and permanent FTEs) by all industries by 2020.

Similarly, the total cumulative output across all industries in the economy would increase by *$30.0 billion* to *$63.2 billion*—and value added would total *$14.8 billion* to *$28.3 billion* over the 2013-2020 period. This growth would support from *160,500* to *215,400* job-years over this period. This is equivalent an average of *20,100* to *26,900* jobs supported each year over the 8 year period during which time the manufacturing capacity would expand to meet the military biofuels demand targets.

A couple of points are worth noting:

- Although not insignificant, the growth in economic capacity and jobs that would be stimulated by the military's investment in growing the advanced biofuels sector is still tiny compared to the overall national economy. For example, the high estimate of direct, indirect and induced value added produced by 2020 ($14.1 billion) as a result of the military biofuels program would add *less than one-tenth of one percent* to the nation's GDP. At the same time, these figures indicate substantial economic gains when compared to the relatively small costs of DoD's current biofuels program.
- The wide range of estimates reflect assumptions we made regarding several important cost variables for each of the value chain sectors, which in turn reflect uncertainties about the feedstock and technologies, as well as other market uncertainties. This bounding exercise was undertaken to evaluate some benefits that fall within the broad range where many technologies might fall.

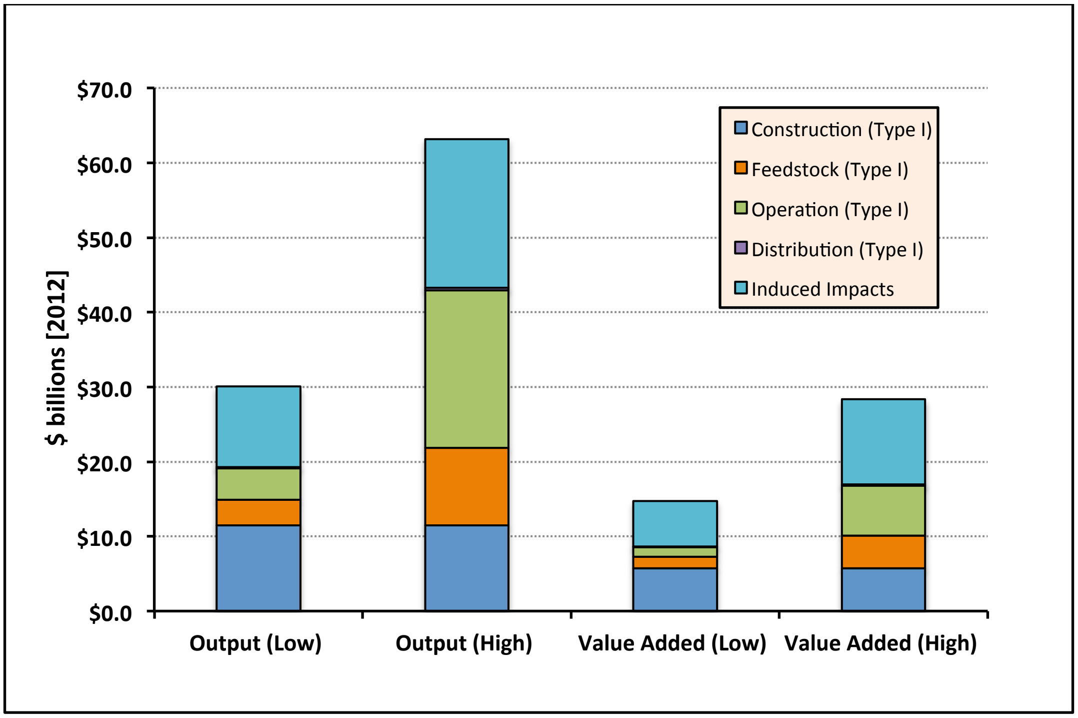
3. *Value-Chain Contributions*

These variations and their effect on the range of possible economic impacts are apparent in the figures below, which allow a more detailed review of the model results for output, value added and jobs, by value-chain sector. Figure 7 shows the high and low estimates for total cumulative direct, indirect and induced outputs and value added over the 2012-2013 period, illustrating the contribution of each value chain sector, and calculated induced impacts (which combines the contribution of the value-chain sectors, to the totals).

Figure 8, however, shows the growth over time of the total *yearly* output that would be added to the economy by 2020, illustrating the contribution of the sectors and

induced impacts, not including the construction sector. Here we look only at production (feedstock and operations) and distribution sectors, which will continue to produce direct, indirect, and induced economic impacts in the years beyond 2020 as long as the military demand continues into the future. Indeed, these impacts are likely to grow, if the military expands its requirement and substitutes a greater share of its fossil-based fuels with advanced biofuels in later years. The construction sector's impacts, though substantial over the 2013 to 2020 period, are temporary, even if they may be felt over a period of years after the last plant is built.

Figure 7—Total Cumulative Indirect, Direct & Induced Impacts 2012-2020 Showing Value-Chain Contributions



A similar pattern is evident in figures 9 and 10 which show, respectively, the total cumulative number of job-years supported over the 2013-2020 period, including the value-chain contributions from production an distribution, excluding construction, and the total number of new jobs added to the economy by 2020, with value-chain and induced impacts contributions.

The relative variations in the impacts on output (and value added) and jobs for the different value-chain sectors reflect both differences in the original direct outputs and jobs, and the values (i.e., *multipliers*) by which the direct impacts are multiplied to estimate the indirect and induced impacts, associated with each sector.

As shown in figure 9, although variations in cost variables for different value-chain sectors still results in a range of job impacts, the high- and low-estimates are closer together than in the output and value-added cases. An important difference, in part,

is that there are no assumed variations in the number of operations jobs—it was thought reasonable to assume that it would require roughly the same number of workers to produce a gallon of biofuels regardless of the assumptions about operations costs and differences in conversion technologies.

Figure 8—Total (High Estimate) Output Added to the Economy by 2020, Showing Feedstock, Operations, and Distribution (Type I) and Induced Impact Contributions

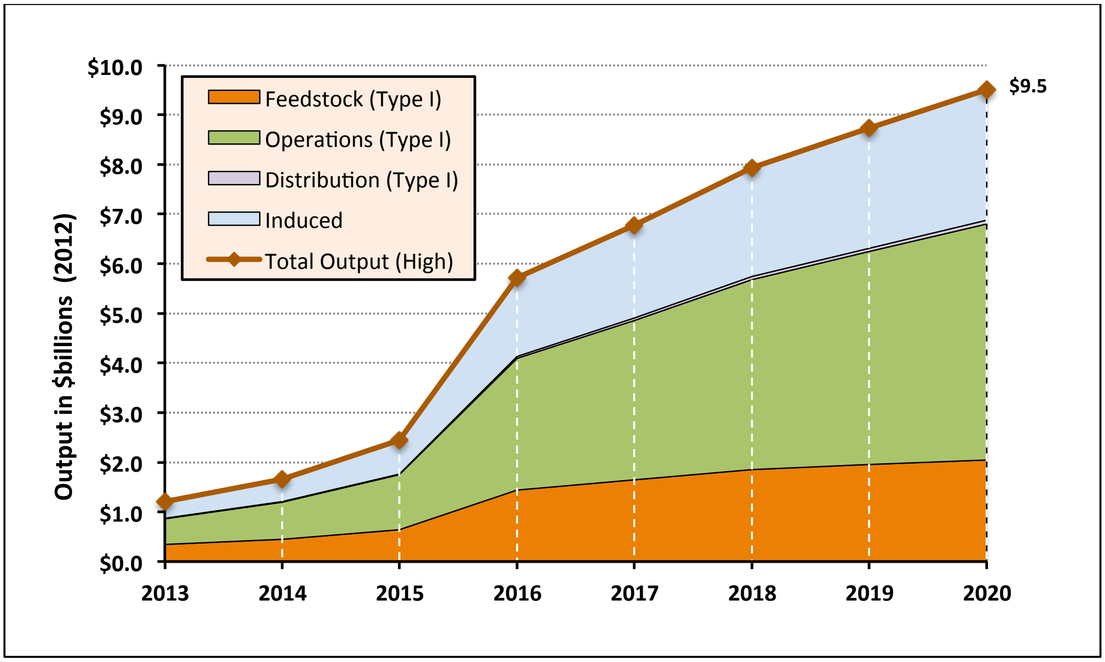
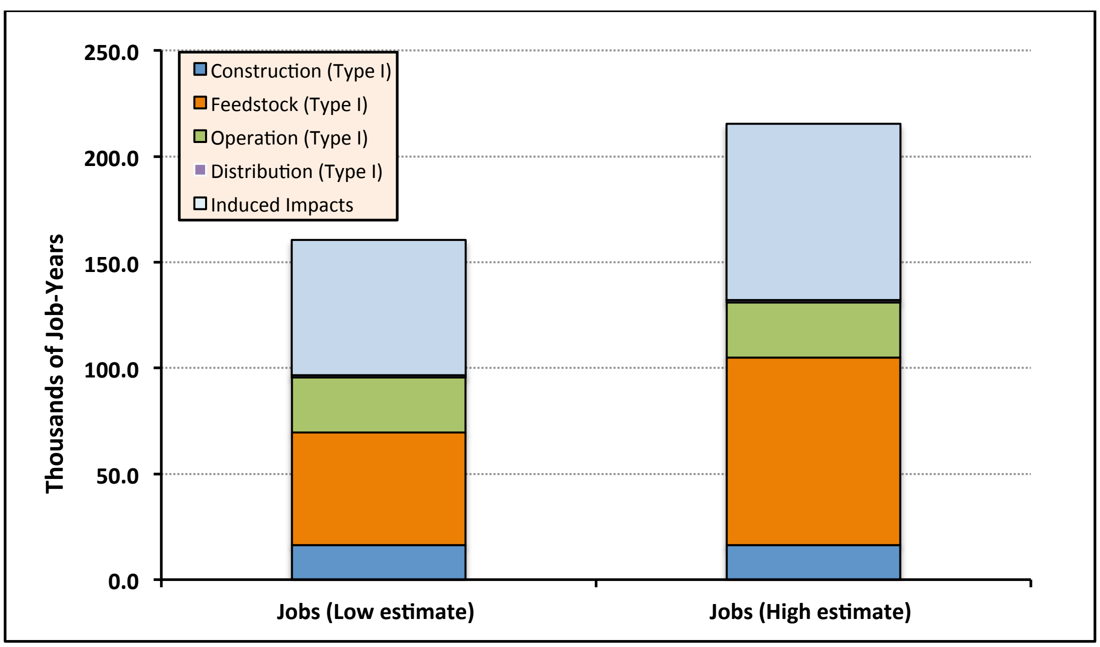


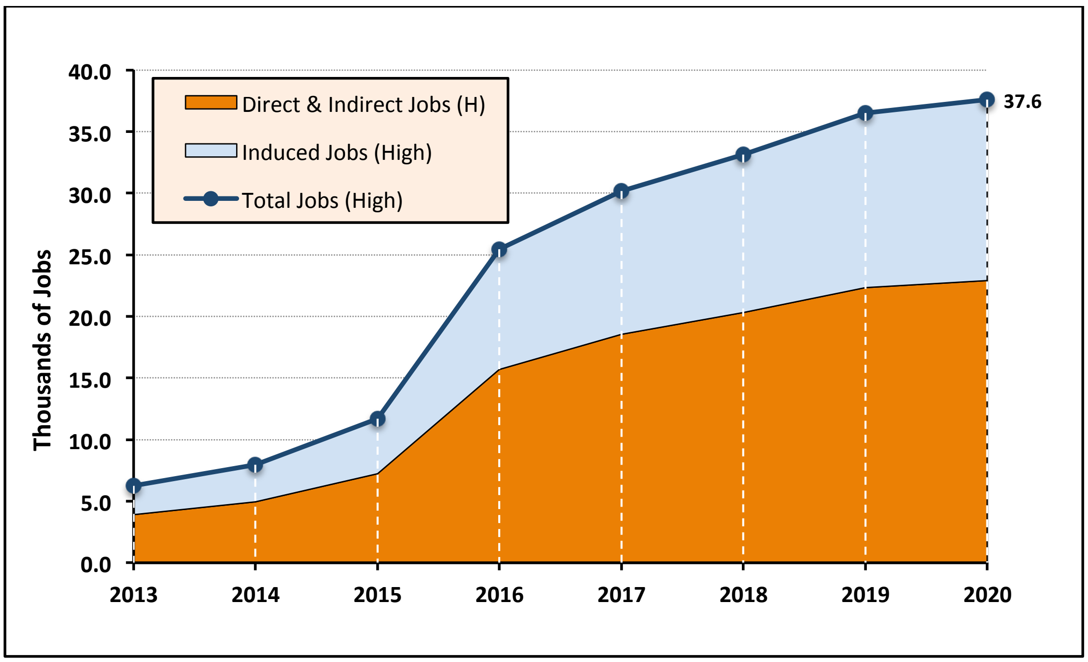
Figure 9—Cumulative Indirect, Direct & Induced Employment Impacts 2012-2020 Showing Value-Chain Contributions



In addition, feedstock direct and indirect jobs impacts are somewhat higher than the construction job impacts. Although both feedstock and construction are relatively labor-intensive, and would employ comparable numbers of workers each year in the military biofuels production scenario (see table 6), the former's employment multipliers (Types I and II) are more than twice those of the latter sector (see appendix A, table A-VI).

Both feedstock production and construction also are much more labor intensive than the operations and distribution sectors in the value chain. Hence, because they directly employ far fewer workers, the latter two sectors' direct, indirect and induced employment impacts are still comparatively very small, even though they have large jobs multipliers. Indeed, the distribution jobs are so small (as are their other impacts), that they barely show up in the charts.

Figure 10—High Estimate of Jobs Supported Yearly Through 2020: Feedstock Production, Operations & Distribution



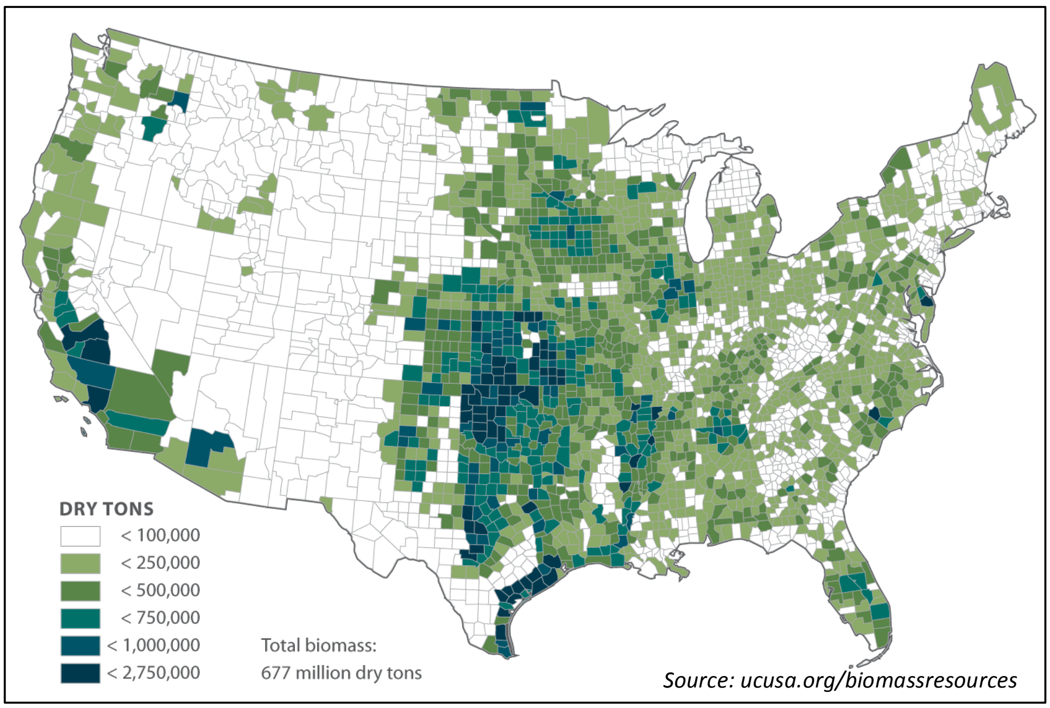
Regional Impacts

The economic impact analysis in our study was done for the nation as a whole. A breakdown of these impacts at the regional and local levels, however, would be very difficult, for both methodological and substantive reasons, that are beyond the scope of the current study. For example, it is not possible to *a priori* identify where drop-in biofuels plants might be located, given the large diversity of feedstock options around the nation. Proximity to adequate supplies of feedstock is a critical factor in siting biofuel production facilities, largely because of transportation costs of

shipping feedstock supplies to the plants. The literature shows that most biofuel plants are located within 100 miles of their feedstock supply.[54] Proximity to the military installations where the fuels would be needed may not be as important a factor, since drop-in fuels should be able to be transported using the existing petroleum-fuel distribution infrastructure.

Multiple kinds of feedstock can be used in the production of drop-in biofuels, as we saw above, from animal fats and oilseed crops to woody and agricultural residues. There are different geographical patterns for where the different types of feedstock can be grown or collected. Animal fats and yellow grease are collected from food processing facilities, and biofuel plants using these feedstock are likely to be found in closer proximity to urban areas than oilseed crops, woody biomass and agricultural residues which are found primarily in rural regions of the country. The wide distribution of non-food sources of biomass—energy crops, agricultural residues, waste materials and forest biomass—is shown in the map in figure 11, developed by the Union of Concerned Scientists.

Figure 11—Total Potential Biomass Resources in the Continental United States



The E2 report and other studies indicate that a large share of biofuel plants are more likely be located in the South or Midwest, reflecting incentives provided by the states to locate there, as well as proximity to feedstock sources.[55] Moreover, the economic gains from the growth in drop-in fuel manufacturing in response to the military biofuels industry, as the Pew report claims, is more likely "to spur job creation and economic opportunities in rural America,"[56] than benefit urban and suburban communities. This would result from the growth of feedstock production

operations as well as construction of the manufacturing plants for processing the feedstock. As our economic impact analysis shows, feedstock production and plant construction would create the largest number of new jobs, in these areas.

"Typical" Regional Impacts

Although we cannot at this time analyze geographical patterns of economic growth that might arise from the military biofuels program, we can use the MBEIA model to look at potential economic impacts of a "typical" drop-in biofuel plant, if it were built in a local region. That is, using the MBEIA model assumptions, and parameters, we can construct a simple model of a "typical" plant and use similar RIMS II multipliers to estimate direct, indirect, and induced outputs, value-added and jobs that might be created if such a plant were to be constructed in a potential biomass appropriate location.

Table 9 summarizes the results of this simulation. We assume that a 50 MGY drop-in biofuels plant will be constructed beginning in 2013, perhaps near a small industrial town in a rural region of the country, and start operation in 2015. We calculate construction, production (feedstock & operations) and distribution expenditures and jobs from that point on through 2020. We then use multipliers to calculate the indirect and induced economic impacts for the region the plant would be located, resulting from the construction and operation of that plant.

Keeping in mind that these are only rough estimates, we are able to estimate that this "typical" plant will directly result in the creation of about *750* construction jobs and once operational, support *491* permanent jobs each year engaged in feedstock production, plant operation, and distribution, or a total of *1,241* new jobs. This corresponds to total direct expenditures of *$365 million* on construction, and *$141 million* directly pumped into the regional economy each year from feedstock production, operations, and distribution of the drop-in biofuels produced by the plant, most of which would likely benefit businesses and workers in the region.

Over the 2012-2020 period this translates into a cumulative total of *$1.2 billion* in direct expenditures for the value-chain as a whole, including *$848 million* for production and distribution expenditures over this period. Correspondingly, we would see a cumulative total of nearly *3,000 job-years* directly supported by the production and distribution of biofuels by the plant over the period it is operational, through 2020.

Using multipliers, we estimate that direct and indirect output resulting from construction of the plant would be $672 million, supporting nearly 1,200 jobs across all industries in the region. For each year of production and distribution of biofuels by the plant, $327 million additional output would be generated, supporting 1,900 jobs. If induced impacts were added, a total output of nearly *$1.6 billion* of output would be generated by all businesses, supporting *5,119* jobs

Table 9—Summary of Regional Economic Impacts —"Typical" 50 MGY Biofuels Plant

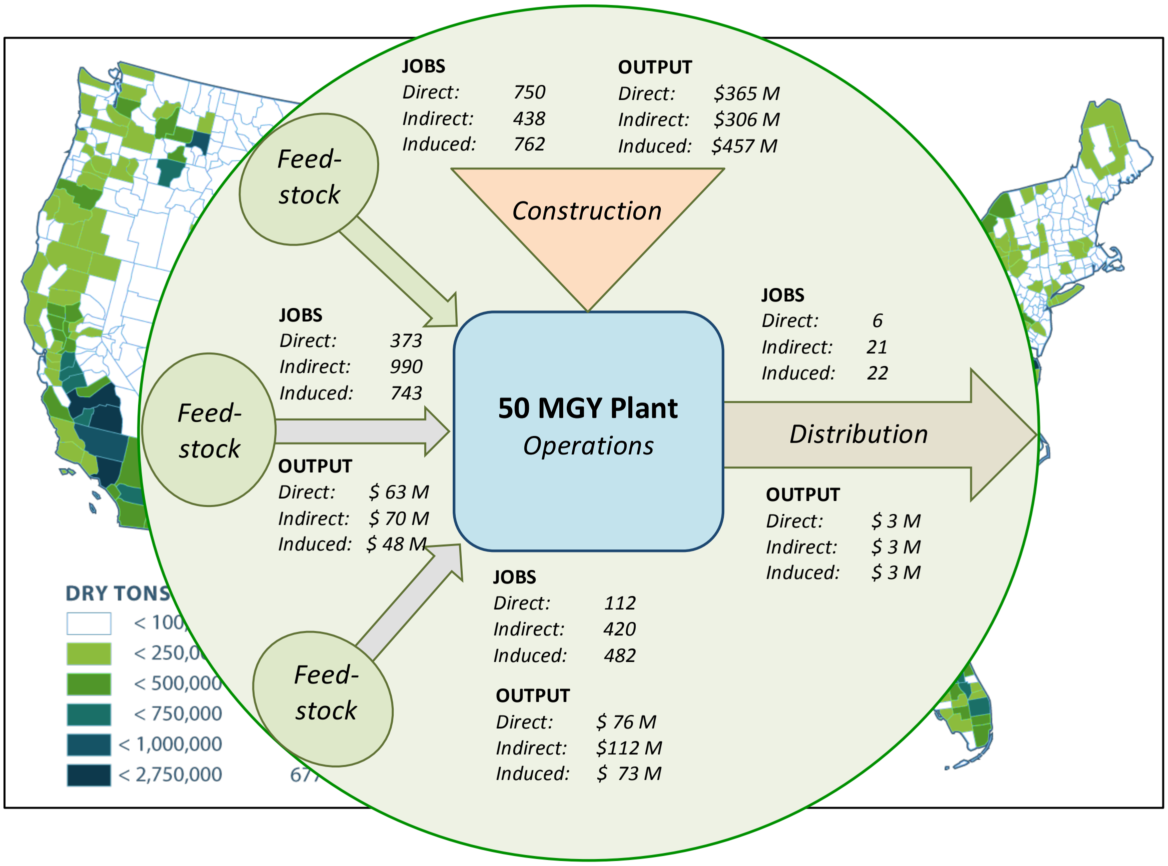
Sector/Impacts	Total Output ($ millions)	Jobs	Value-Added ($ millions)
CONSTRUCTION			
Direct & Indirect	*$671.5*	*1,188*	*$338.7*
Direct, Indirect & Induced	*$1,128.6*	*1,950*	*$599.5*
PRODUCTION & DISTRIBUTION			
Direct & Indirect	*$326.6*	*1,922*	*$117.6*
Direct, Indirect & Induced	*$450.8*	*3,169*	*$458.7*
TOTAL BIOFUELS PLANT IMPACTS			
Direct & Indirect	*$998.0*	*3,110*	*$456.3*
Direct, Indirect & Induced	*$1,578.4*	*5,119*	*$1,058.2*

Using the appropriate multipliers, total cumulative direct and indirect impacts generated in the region would equal *$2.6 billion*, inclusive of nearly *$2 billion* for production and distribution, supporting a cumulative total of over *12,700 job-years* (inclusive of *11,530 job-years* for production and distribution). If we add in induced impacts, the cumulative output resulting from constructing and operating the plant over the 8-year period would total *$3.8 billion*, supporting a cumulative total of nearly *21,000 job-years* (inclusive of *19,000 job-years* for production and distribution).

The schematic in figure 12 presents a more detailed breakdown of the indirect, direct and induced impacts (output, jobs) resulting from the construction of the plants. The output values for feedstock production, operations and distribution numbers represent the output impacts generated from operating the plant *each year*. The jobs numbers represent the total permanent jobs created across the regional economy for these value-chain sectors.[57]

After construction is completed, which would pump in a great deal of money into the local economy, and employ many workers, feedstock production would be the largest sustainable source of revenues and jobs in the biofuel plant's value-chain, followed by operations. Because we are using national multipliers,[58] the numbers are likely to be different from their actual levels if we used multipliers specific to a given region or locale. Nevertheless, these are not insignificant amounts, and would be an important contribution to a rural regional economy.

Figure 12—Regional Direct, Indirect, and Induced Economic Impacts From Construction of a "Typical" 50 MGY Biofuels Plant



Conclusion

In the 1960s, the U.S. Air Force became the first customer of the newly invented integrated circuit. It purchased them in large quantities for use in its Minuteman Missile systems, and later for a large array of other military applications. The military's investments, which included research and development, and later, support for commercialization initiatives such as Sematech (a semiconductor manufacturing consortium) were instrumental in the launch and growth of the microelectronics industry in the United States. It also helped spawn other major technological innovations that have spurred economic growth on a massive scale, including, most notably, the Internet.

The Pentagon appears poised to play a similar role in spurring the large-scale commercial growth of the still embryonic advanced biofuels industry, while also helping to meet a critical national security goal, reducing U.S. dependency on foreign sources of petroleum. The purpose of our current study is to shed light on how the military program could spur rapid capacity growth in this segment of the biofuels industry, and assess its potential economic benefits to the U.S. economy. Through

its earlier tests of drop-in biofuels the DoD determined that it would be possible to make new biofuels that could blend with and substitute for their petroleum-based biofuels. Both the Air Force and Navy set targets for replacing at least half their petroleum-based fuels used aircraft and ships by 50 percent by 2020.

To assess the economic implications we developed and applied a first-order economic impact model. The model helps identify what the extent and nature of the impacts might be in terms of output, value added and jobs. We find that there likely would be a modest but not insignificant economic gains for the nation, and probably for many regional economies around the country. It would produce tens of thousands of jobs and billions of dollars in new revenues.

The implications transcend the military's objectives, however. As the drop-in biofuels industry grows and becomes economically competitive and commercially viable, it could potentially play an increasingly major role in supplying the commercial aviation industry with non-fossil fuels. It has been noted that the U.S. Air Force fuel requirements are equivalent only to a mid-sized airline.[59] The DoD's OES reports that the Pentagon is partnering with the Commercial Aviation Alternative Fuels Initiative, Air Transport Association and American Society for Testing Materials International to promote the development, certification, commercialization and marketing of alternative fuels.[60] This could be transformative for the civilian aviation industry, providing clean fuels at affordable prices.

Sources

Bain, R. L. World Biofuel Assessment. World Biomass Potential: Technology Characterizations. National Renewable Energy Laboratory. NREL/MP-510-42467. December 2007.

Bio-Economic Research Associates (bio-era). U.S*. Economic Impact of Advanced Biofuels: Perspectives to 2030.* February 2009.

Biomass Research & Development Initiative (BRD&Di). *Increasing Feedstock Production for Biofuels, Economic Drivers, Environmental Implications, and the Role of Research.* Biomass Research & Development Board. N.D.

Bureau of Economic Analysis, U.S. Department of Commerce. *RIMS II, An Essential Tool for Regional Developers and Planners.* www.bea.gov.

California Air Resources Board (CARB). "Proposed Regulation to Implement the Low Carbon Fuel Standard – Initial Statement of Reasons – Volume 1" 2009. Retrieved April 23, 2010 from http://www.arb.ca.gov/fuels/lcfs/030409lcfs_isor_vol1.pdf.

Carriquiry, Miguel A., Xiaodong Du, and Govinda R. Timilsina. "Second-Generation Biofuels, Economics and Policies." Policy Research Working Paper 5406. Development Research Group, Environment and Energy Team, The World Bank. August 2010.

Chen, Xiaoguang, Madhu Khanna and Sonia Yeh. "Stimulating Learning-by-Doing in Advanced Biofuels: Effectiveness of Alternative Policies." Department of Agricultural and Consumer Economics, University of Illinois at Urbana Champaign. 2012.

Danigole, Mark S., *Biofuels*, *An Alternative to US Air Force Petroleum Fuel Dependency.* Occasional Paper No. 62, Center for Strategy and Technology, Air University, Maxwell Air Force Base. December 2007.

Hettinga, W.G., H.M. Junginger, S.C. Dekker, M. Hoogwijk, A.J. McAloon and K.B. Hicks. "Understanding the reductions in US corn ethanol production costs: An experience curve approach." *Energy Policy 37* (2009) 190-203.

Jones, S.B., C. Valkenburg, C.W. Walton, J.E. Holladay, D.J. Stevens, C. Kinchin and S. Czernik. *Production of Gasoline and Diesel from Biomass via Fast Pyrolysis, Hydrotreating and Hydrocracking: A Design Case.* PNNL-18284. Prepared for the U.S. Department of Energy under Contract DE-AC05-76R01830. Pacific Northwest National Laboratory (PNNL). February 2009.

National Research Council of the National Academies (NRC). Committee on Economic and Environmental Impacts of Increasing Biofuels Production, Board on Agriculture and Natural Resources, and Board on Energy and Environmental Systems. *Renewable Fuel Standard, Potential Economic and Environmental Effects of U.S. Biofuel Policy.* (National Academies Press, Washington, DC, 2011).

Parker, Nathan. "Modeling Future Biofuel Supply Chains using Spatially Explicit Infrastructure Optimization." Research Report-UCD-ITS-RR-11-04. Institute of Transportation Studies, U.C. Davis. January 2011.

Parker, N. Q. Hart, P. Tittmann and B. Jenkins. "National Biofuel Supply Analysis." Prepared for the Western Governor's Association, Contract 20113-03. Institute of Transportation Studies, U.C. Davis. April 2011.

The Pew Project on National Security, Energy and Climate. *From Barracks to the Battlefield, Clean Energy Innovation and America's Armed Forces.* The Pew Charitable Trusts. 2011.

Rismiller, Craig W. and Wallace E. Tyner. "Cellulosic Biofuels Analysis: Economic Analysis of Alternative Technologies." *Working Paper #09-06.* Department of Agricultural Economics, Purdue University. June 2009.

Solecki, Mary, Anisa Dougherty, and Bob Epstein. *Advanced Biofuel Market Report 2012, Meeting U.S. Fuel Standards.* Environmental Entrepreneurs. 2012.

The University of California, Davis and The University of California, Berkeley. *California Renewable Diesel Multimedia Evaluation, Tier I Report. Prepared* for the California Environmental Protection Agency, Multimedia Working Group. December 2010.

U.S. Department of Defense. *Operational Energy Strategy: Implementation Plan.* March 2012.

U.S. Environmental Protection Agency (EPA). *Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis.* EPA-4200-R-100-006. February 2010.

NOTES

1 Mark S. Danigole, *Biofuels, An Alternative to US Air Force Petroleum Fuel Dependency.* Occasional Paper No. 62, Center for Strategy and Technology, Air University, Maxwell Air Force Base. December 2007: 8.

2 Ibid. 1, 6.

3 Diane Cardwell, "Military Spending on Biofuels Draws Fire," *The New York Times,* August 27, 2012.

4 U.S. Department of Defense (DoD). *Operational Energy Strategy: Implementation Plan.* March 2012.

5 DoD, *Operational Energy Strategy*. 1

6 Danigole, *Biofuels.* 4.

7 "Navy Secretary Pushes for Alternative Use." Story Number: NNS11026-05. 16, January 2011. www.Navy.mil.

8 Danigole, *Biofuels.* 4

9 The Pew Project on National Security, Energy and Climate. *From Barracks to the Battlefield, Clean Energy Innovation and America's Armed Forces.* The Pew Charitable Trusts. 2011. 16.

10 "New Biofuel Markets to Reduce Foreign Oil Dependence." Story Number: NNS110816-18. Navy.mil. August 16, 2011.

11 Ray Mabus, "Remarks by the Honorable Ray Mabus, Secretary of Navy, Green Hornet." Patuxent River naval Air Station, MD. 22 April 2010. Overall, every increase of one-dollar per barrel of oil adds $130 million to the Defense Department's budget. Norman Seip, "Push in Congress to ban biofuels in military has big long-term costs." The Christian Science Monitor. 16 July 2012. http://www.csmonitor.com/Commentary/Opinion/2012/0716/Push-in-Congress-to-ban-biofuels-in-military-has-big-long-term-costs. The DoD, in fiscal year 2011 consumed 5 billion gallons of petroleum, primarily for operations and training. A Pew reports similarly comments that because of rising energy prices, although the DoD's energy use declined from 2009 to 2011 by more than 9 percent, its operational energy costs rose from 2009 to 2011 by more than 19 percent. Pew, *From Barracks to the Battlefield.* 16.

12 Mary Solecki, Anisa Dougherty, and Bob Epstein. *Advanced Biofuel Market Report 2012, Meeting U.S. Fuel Standards.* Environmental Entrepreneurs. 2012. 13.

13 "Triple Win for Biofuels on Capitol Hill; $$ for Military Biofuels; Tax Extenders Package; Algae wins tax credit parity." *Biofuelsdigest.com*. August 3, 2012. http://www.biofuelsdigest.com/bdigest/2012/08/03/triple-win -for biofuels-on-capitol hill-100m-for-military-biofuels-tax-extenders-package-algae-wins-tax-credit-parity/

14 Cardwell, "Military Spending on Biofuels."

15 Ibid.

16 Zack Colman, White House pushes biofuels on Navy over lawmaker objections," E2 Wire. Thehill.com. July 2, 2012

17 Mabus, "Remarks."

18 National Research Council of the National Academies (NRC). *Renewable Fuel Standard, Potential Economic and Environmental Effects of U.S. Biofuel Policy.* (National Academies Press, Washington, DC, 2011).

19 For more detailed information on drop-in fuels and biodiesel see the DOE's Alternative Fuels Data Center (AFDC) website: www.afdc.energy.gov. This does not preclude use of biodiesel fuels for other military applications, such as vehicles, generators and non-aviation equipment. However, our study assumes that the drop-in fuels that would meet the alternative fuels criteria to meet the Air Force and Navy targets would probably not include most biodiesel fuels (www.afdc.energy.gov/fuels/biodiesel.html).

[20] See for example: Bain, R. L. World Biofuel Assessment. World Biomass Potential: Technology Characterizations. National Renewable Energy Laboratory. NREL/MP-510-42467. December 2007. S.B. Jones et al. *Production of Gasoline and Diesel from Biomass via Fast Pyrolysis, Hydrotreating and Hydrocracking: A Design Case.* PNNL-18284. Prepared for the U.S. Department of Energy under Contract DE-AC05-76R01830. Pacific Northwest National Laboratory (PNNL). February 2009; Craig W. Rismiller and Wallace E. Tyner. "Cellulosic Biofuels Analysis: Economic Analysis of Alternative Technologies." *Working Paper #09-06;* Department of Agricultural Economics, Purdue University. June 2009; U.S. Environmental Protection Agency (EPA). *Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis.* EPA-4200-R-100-006,. February 2010.

[21] DoD, *Operational Energy Strategy*. 17

[22] Ibid.

[23] Pew, *From Barracks to the Battlefield.* 16.

[24] DoD, *Operational Energy Strategy*. 17.

[25] See Ian Graham, "Air Force Scientists Test, Develop Bio Jet Fuels," *Defense.gov News Article*. March 30, 2010. Maj. Richelle Dowdell. "Officials certify first aircraft for biofuel usage." *Air Force Print News Today,* 10, February 2011. www.af.mil. In 2010 the Air Force A-10 Thunderbolt II flew solely on a blend of conventional JP-8 jet fuel, the first flight of its kind.

[26] Solecki et al. *Advanced Biofuel Market Report 2012*. 14.

[27] "First Navy Trainer Completes Biofuel Flight at Patuxent River." Story Number: NNS110825-06. Successful Navy and Marine biofuel demonstrations using 50-50 blends of biofuels also have been used in numerous test flights, including the T-45 "Goshawk" training aircraft, the F/18 "Green Hornet," MH-0S, F/A-18 D, MV-22 Osprey and MH-60 sea hawk helicopters.

[28] Pew, *From Barracks to the Battlefield.* 37. The Navy has also been testing alternative fuels on its boats and riverine craft, including, in October 2010, a Navy test of the Riverine Command Boat-Experimental (RCB-X) on an algae-based biofuel.

[29] Specialist 3rd Class Renee L. Candelario. "GreatGreenFleet: USS Nimitz Receives Biofuel." Story Number: NNS120718-05. 18 July, 2012. www.navy.mil.

[30] Pew, *From Barracks to the Battlefield.* 8.

[31] Danigole, *Biofuels.* 24.

[32] Ibid*.* 35.

[33] Danigole, *Biofuels.* 24.

[34] DoD, *Operational Energy Strategy*. 17.

[35] Graham, "Air Force Scientists Test."

[36] Karen Parrish, "Navy to Demonstrate Biofuel Use During Exercise." *Armed Forces Press Service, U.S. Department of Defense.* December 5, 2011. http://www.defense.gov/news/newsarticle.aspx?id=66359.

[37] Danigole, *Biofuels;* Graham, "Air Force Scientists Test."

[38] Mabus, "Remarks."

[39] See the AFDC website: http://www.afdc.energy.gov/fuels/emerging_dropin_biofuels.html.

[40] Ibid.

[41] See http://www.afdc.energy.gov/fuels/emerging_green.html.

[42] EPA. *Renewable Fuel Standard Program.* 767. F-T technology is commonly termed biomass-to-liquids (BTL) because of its similarity to gas-to-liquids and coal-to-liquids technology.

[43] Alternative fuels Data Center, DOE.

[44] S.B Jones et al. *Production of Gasoline and Diesel*. 4.3.

---

[45] See http://www.afdc.energy.gov/fuels/emerging_green.html.Producing The AFDC site states that HDRD involves hydrogenating triglycerides to remove metals and compounds with oxygen and nitrogen using existing refinery infrastructure. Dedicated hydrotreating facilities that do not use conventional petroleum can also produce HDRD.

[46] Munoz, et al. Production of Renewable Diesel Fuel. National Institute for Advanced Transportation Technology, University of Idaho. June 2012. Accessible at: http://www.webs1.uidaho.edu/niatt/research/Final_Reports/KLK766_N12-08.pdf.

[47] Graham, "Air Force Scientists Test."

[48] "Navy Secretary and USDA Secretary Announce Largest Government Purchase of Biofuel. Story Number: NNS111305-06. *Navy.mil.* December 5, 2011; Cardwell, "Military Spending on Biofuels."

[49] DoD, *Operational Energy Strategy*. 1.

[50] Bio-Economic Research Associates (*bio-era*). U.S*. Economic Impact of Advanced Biofuels: Perspectives to 2030.* February 2009. This is in line with the bio-era report, which notes that it is "comparable to the capacity utilization factor for petroleum refineries, which averaged 89.5 percent from 1985 to 2007, and that for corn-based ethanol plants, which typically operate at average utilization rates of 90-95 percent." (p. 4.)

[51] Danigole, *Biofuels.*

[52] NRC, *Renewable Fuel Standard.* 123.

[53] For more information about the RIMS II methodology see, Bureau of Economic Analysis (BEA), U.S. Department of Commerce. *RIMS II, An Essential Tool for Regional Developers and Planners.* www.bea.gov.

[54] Parker, N. Q. Hart, P. Tittmann and B. Jenkins. "National Biofuel Supply Analysis." Prepared for the Western Governor's Association, Contract 20113-03. Institute of Transportation Studies, U.C. Davis. April 2011. vi-vii.

[55] Solecki et al. *Advanced Biofuel Market Report 2012*.

[56] Pew, *From Barracks to the Battlefield,*

[57] Indirect impacts are calculated by subtracting direct impacts from Type I (direct+indirect) impacts, derived using the RIMS II multipliers; induced impacts are calculated by subtracting Type I impacts from Type II (direct+indirect+induced) impacts. For more information about the see: BEA, *RIMS II*.

[58] More precisely, the multipliers were compiled by the BEA for region defined as the 48 contiguous states and District of Columbia. It does not include Alaska, Hawaii or U.S. territories.

[59] Graham, "Air Force Scientists Test." Graham notes that although the Air Force is the largest DoD consumer of jet fuel, it "burns only the equivalent of a mid-sized airline." He reports in addition, the Air Force is closely cooperating with industry as part of a consortium of commercial airlines and engine manufacturers called the Commercial Aviation Initiative. The expectation is that once biofuels are certified for use, production economies of scale will make them affordable, on par with petroleum-based jet fuel.

[60] DoD, *Operational Energy Strategy,* 17.

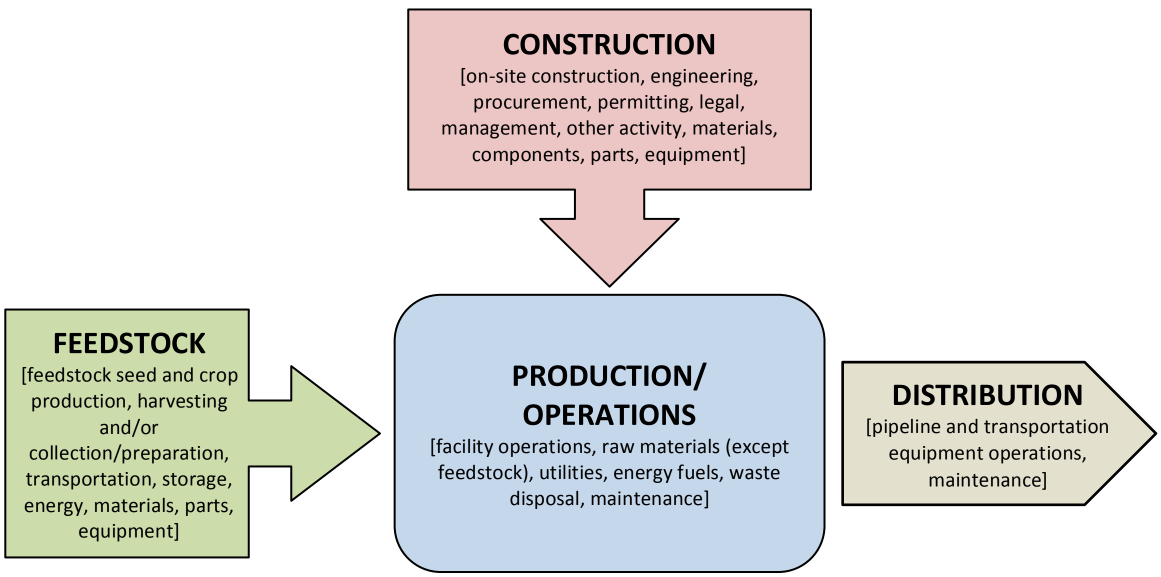
Technical Appendix

The Military Biofuels Economic Impact Analysis Model

Model Overview and Methodology

The Military Biofuels Economic Impact Analysis (MBEIA) model is a first-order spread-sheet model based on the cost-structure of the main sectors of the advanced biofuels value-chain. Figure A-1 schematically illustrates the value-chain sectors with some detail on their principal cost factors (labor costs are assumed for all sectors). The model first calculates the expenditures associated with each sector as new plants are built, and then produce and distribute biofuels in response to the projected demand created by the military's alternative fuel targets.

Figure A-1: Advanced Biofuels Value-Chain



These expenditures are input into the larger economy, as they represent spending for goods and services, and support workers that produce and deliver them, used in the value-chain sectors. This spending output from the value-chain sectors not only generates outputs and jobs resulting directly from the production of the biofuels. It ripples through the economy, stimulating new activity by other businesses sectors' supply chains (*indirect* output), and consumer spending by workers resulting from income changes in the directly and indirectly affected sectors (*induced* output). Applying appropriate *multipliers*, the MBEIA model calculates the indirect and induced economic impacts, including the resulting output, jobs, and value-added from this spending

Summary of Assumptions

Table A-I presents the primary assumptions used in the model for calculating the costs or expenditures incurred by the four value-chain sectors in growing the capacity needed to meet the military alternative fuels goals.

Table A-I: MBEIA Model Assumptions

Construction Cost Assumptions

Initial 2012 plant construction cost estimates (millions of $2012):

Costs/Plant size	10 MGY	20 MGY	50 MGY	75 MGY
Construction Costs	$227	$322	$365	$256
Nameplate Unit Costs ($2012/Gallon)	$22.75	$16.09	$7.30	$3.41

Assumes construction takes place over multiple years depending on size:

Plant size	*Construction Period*	*Investment Schedule*
Under 50 MGY	1½ – 2 years	1st year–40%; 2nd year–60%
50 MGY or greater	2½ – 3 years	1st year–8%; 2nd year–60%; 3rd year–32%

Assumes construction cost values at year of ground breaking, not year of completion.
Assumes that each plant size, construction costs decline 20 percent from 2013 to 2020

Note: Existing capacity (85 MGY) was not included in the calculating, though the construction costs for new planned capacity (35 MGY) were included.

Feedstock Cost Assumptions

Low- and high-end initial feedstock costs per BDT ($2012) and feedstock yields (Gallons/BDT):

Low Cost Feedstock ($/BDT)	High Cost Feedstock Cost ($/BDT)	Low Yield Estimate (Gallons/BDT)	High Yield Estimate (Gallons/BDT)
$70	$125	60	100

Assumes plants operate at 90 percent capacity
Assumes feedstock supply costs and yields for each plant size decline 20 percent from 2013-2020

Operating Cost Assumptions

Looks at a high-end and low-end unit operating cost scenario:

Low-end cost=$0.50/gallon ($2012)	High-end cost = $2.50/gallon ($2012)

Distribution Cost Assumptions

Low and high end distribution costs per gallon of fuel ($2012) estimates:

Low-end cost=$0.02/gallon	High-end cost = $0.05/gallon

Assumes plants operate at 90 percent capacity

MGY=million gallons per year; BDT=bone dry tons

Advanced Biofuels Capacity Scenario

The first step in developing the MBEIA model is to identify a scenario that we could use to characterize the growth in advanced biofuels production capacity to meet the military alternative fuels targets. The Department of Defense (DoD) *Operational*

Energy Strategy (OES) released in March 2012 identified two goals for the use of alternative fuels:[1]

- The Air Force has called for cost-competitively meeting 50 percent of its domestic aviation fuel requirement—approximately *387 million gallons per year* (MGY)—via an alternative fuel source by 2016;
- The Navy wants to use alternative sources for half of all energy consumption afloat by 2020—requiring at about *300 MGY* of advanced biofuels capacity.[2]

That is, the military has called for acquiring at least *687 MGY* of alternative fuels to meet both services' goals by 2020. Assuming, a capacity utilization of 90 percent for biofuels production plants in this scenario,[3] the total domestic alternative fuels *production capacity* that would be needed is approximately *430 MGY* by 2016 to meet the Air Force goal, and about 340 MGY by 2020 to meet the Navy goals—or minimum of *770 MGY* new capacity by 2020 meet the both goals.

The literature and empirical evidence about the growth of existing biofuels capacity (E2, 2012) indicate that the plants built to meet this target could come in a range of sizes. We roughly follow the approach of the *bio-era* study (*bio-era*, 2009), and assume that production capacity to meet the military targets over the 2013-2014 period would come in increments of 10 MGY, 20 MGY, 50 MGY, and 75 MGY. Although larger capacity facilities theoretically are possible—and these are projected, for example, in the *bio-era* study—there are no examples of plants 100 MGY or larger currently in existence producing advanced biofuels, though there are a handful large-scale plants proposed for future years. We stick with a scale of plant size for which we have actual empirical data.[4]

In constructing a plant capacity scenario for our analysis, we know from available data that there already exists sufficient production capacity—in operation or under construction—capable of providing the kinds of fuels (i.e., "drop-in" fuels) that meet the military's alternative fuels criteria, to meet approximately 120 MGY of the military targets. For example, Dynamic Fuels' 75 MGY plant in Geismar, LA mentioned above, has been supplying fuels to the military derived from non-food grade animal fats and grease. KiOR is constructing a 11 MGY plant in Columbus, MS and breaking ground on a new 33 MGY plant in Natchez, MS which converts southern yellow pine chips to make drop-in grade diesel fuels.[5]

---

1 U.S. Department of Defense. *Operational Energy Strategy: Implementation Plan.* March 2012. 17.

2 Ibid.

3 Bio-Economic Research Associates (*bio-era*). U.S*. Economic Impact of Advanced Biofuels: Perspectives to 2030.* February 2009. 4.

4 National Research Council (NRC) of the National Academies.. *Renewable Fuel Standard, Potential Economic and Environmental Effects of U.S. Biofuel Policy.* (National Academies Press, Washington, DC, 2011). Table 2.3.

5 Mary Solecki et al. *Advanced Biofuel Market Report 2012, Meeting U.S. Fuel Standards.* Environmental Entrepreneurs. 2012. Electronic communications with Mary Solecki, Sept. 2012.

Therefore, in our scenario, we assume that the ramp-up period for providing new capacity will begin with approximately 85 MGY of capacity already in place (a 10 MGY plant and 75 MGY plant) and another 35 MGY plant expected go online by 2014. As a result, a total of *650 MGY* of additional capacity, in addition to the existing and planned capacity, would need to be built to produce the quantity of advanced biofuels required to meet the military alternative fuels goals.

Table A-II (repeating table 1 in the main text) presents the capacity growth scenario we used in the MBEIA model for calculating the economic impacts of the military biofuels program. Although more than one scenario to reach this goal is probably possible, the end result is likely the same in overall magnitude of impacts. We therefore believe that the scenario we use is a good first approximation for meeting the Air Force and Navy targets.

Table A-II: Drop-In Capable Biofuels Processing Facilities

	Existing or Planned Capacity		New Installed Capacity (Number of New Plants)				Total New Capacity		Total Operating Capacity	
Year	No. Plants	Total Capacity (MGY)	10 MGY	20 MGY	50 MGY	75 MGY	No. New Plants	New Capacity (MGY)	No. Plants	Total Capacity (MGY)
2013	2	85	0	0	0	0	0	0	**2**	**85**
2014	1	35	0	0	0	0	0	0	**3**	**120**
2015			2	2	0	0	4	60	**7**	**180**
2016			2	4	3	0	9	250	**16**	**430**
2017			0	2	1	0	3	90	**19**	**520**
2018			0	0	2	0	2	100	**21**	**620**
2019			0	0	0	1	1	75	**22**	**695**
2020			0	0	0	1	1	75	**23**	**770**
TOTAL	**3**	**120**	**4**	**8**	**6**	**2**	**20**	**650**	**23**	**770**

Our capacity scenario is informed by assumptions concerning how fast new plants can be designed, built and started-up to reach full production capacity, which also affects the timing of adding new capacity. Based on our review of studies that have developed detailed engineering-economic models of biofuels plants, we assume plants of under 50 MGY will require a period of 1.5 to 2 years to build, and plants 50 MGY or larger will require approximately 2.5 to 3 years to come online. As indicated in the assumptions table, table A-I, these assumptions affect the year-by-year output and jobs impacts associated with plant construction expenditures, but not the total impacts over the 2013-2020 period covered by our study.

Construction Expenditures Calculations

The assumptions in table A-I used for construction expenditures for the new capacity added to meet the military fuel targets, include the initial plant construction costs for each plant size used in the model. These cost numbers are estimated based on a review of existing facilities and studies of advanced biofuel

feedstock and conversion pathways. We also assume that as a result of experience and learning, construction costs per gallon will decline 20 percent between 2013 and 2020, which is about the same that the *bio-era* study predicts in its study over this same period.[6]

The construction costs for the plants analyzed in the studies tend to cluster around two type of plants with different conversion pathways, feedstock and capacities, as described in Box A in the main text: (i) pyrolysis-hydroheating and related process technologies converting plant oils and animal waste feedstock; and, (ii) thermochemical gasification combined with Fischer-Tropsch and/or pyrolysis and hydro-treatment processes converting biomass (woody and agricultural residues), to produce "drop-in" renewable diesel fuels. The latter tend to cost more to build compared to the former types of plants.

Table A-III summarizes examples of plants evaluated in the literature, comparing capital costs for different plant sizes, and ordered by plant size. It also shows the nameplate capital costs/gallon of fuel, calculated by dividing the total capital costs by plant capacity. The plants were selected according to the kinds of process technology and fuels they produce, which are most similar to the drop-in renewable diesel fuels that meet military fuels requirements.

Table A-III: Construction Costs for Different Plant Sizes and Conversion Process Technologies in the Evidence

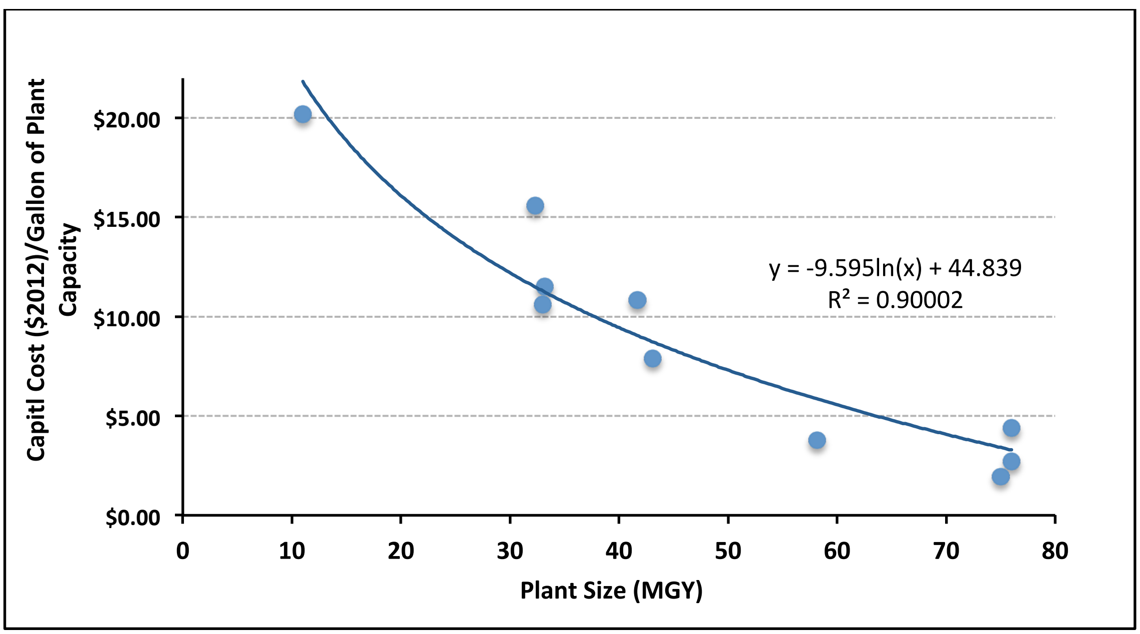
Source	Conversion Process	Plant Size (MGY)	Capital Cost ($2012 million)	Capital Cost/Gal ($2012)
Jones et al (2009)	Pyrolysis Hydrotreating-Integrated	76	208	$2.73
Jones et al (2009)	Pyrolysis Hydrotreating-Stand Alone	76	334	$4.40
Dynamic Fuels (Solecki, 2012)	Hydrogeneration	75	145	$1.93
NRC (2011)	Pyrolysis, Hydrogen Purchase	58	220	$3.79
NRC (2011)	Pyrolysis-KIOR	43	340	$7.89
NRC (2011)	Gasification and F-T High Temp	42	451	$10.82
EPA (2010)	Renewable Diesel-Thermochemical-Pyrolysis Hydro-treating	33	350	$10.61
KiOR (Solecki, 2012)	Thermochemical-Pyrolysis-Hydrotreatment	33	382	$11.50
NRC (2011)	Gasification and F-T High Temp	32	504	$15.60
KiOR (Solecki, 2012)	Renewable Diesel-Thermochemical-Pyrolysis Hydrotreating	11	222	$20.18

6 *bio-era*, U.S. *Economic Impact of Advanced Biofuels:22, table A3.*

Three of the plants are identified in the E2 market report (E2, 2012) and include two plants—the 75 MGY Dynamic Fuels plant and the 11 MGY KiOR plant—already under construction and the third—a 33 MGY KiOR plant—expected to go online in 2014, that represent the existing and planned capacity plants in the capacity scenario. The first plant cost $222 million and the second is estimated to cost $350 million. On the other hand, the Dynamic Fuels 75 MGY plant that is converting animal fats and grease to drop-in fuels for military tests cost only $145 million to build.[7] The Pacific Northwest National Laboratory (PNNL) study estimated that a stand-alone 76 MGY plant producing "infrastructure-capable hydrocarbon biofuels," processing hybrid poplar wood via a "fast" pyrolysis-hydrotreating pathway, would cost $334 million to build. However, PNNL estimates that an integrated plant, which co-locates the biofuels processing plant with an existing petroleum refinery for separating and finishing into hydrocarbon fuels would only cost $208 million, in today's dollars.[8]

A scatter plot matching capital costs/gallon with plant size shown in figure A-2 reflects the economies of scale that would be expected, i.e., capital costs per unit of fuel would steadily decline as plant size increases.

Figure A-2: Plot of Plant Size and Capital Cost Per Gallon of Plant Capacity



---

7 NRC, *Renewable Fuel Standard, 144..* See also: http://www.louisianaeconomicdevelopment.com/case-studies/dynamic-fuels.aspx

8 S.B. Jones et al. *Production of Gasoline and Diesel from Biomass via Fast Pyrolysis, Hydrotreating and Hydrocracking: A Design Case.* PNNL-18284. Prepared for the U.S. Department of Energy under Contract DE-AC05-76R01830. Pacific Northwest National Laboratory (PNNL). February 2009.

Using the statistical regression trend formula calculated by the spreadsheet software, which shows a very strong correlation with the data in the plot, we estimate the construction costs associated with the plant sizes (10 MGY, 20 MGY, 50 MGY and 75 MGY) used in the model (shown in table A-I). For example, for a given year and plant size, plant construction expenditures are equal to the plant costs for that plant size times the number of plants under construction—adjusted depending on where the construction is in the investment schedule in table A-I; for example, the calculated costs for a 75 MGY plant would be multiplied by 60 percent in the second year of its under construction.

The lower cost for the 75 MGY plants in the scenario could reflect conversion process technologies and feedstock that result in lower cost construction costs (include the capability of co-location with petroleum refineries) for the larger scale plants. This could be considered a conservative assumption in the economic impact analysis, since lower construction expenditures translates into lower economic impacts in the model. Similarly, the assumption that construction costs steadily decline over time with experience, also results in lower economic impacts than if we assumed the costs do not change over time.

Feedstock Production Expenditures Calculations

Selecting the values for the two principal parameters used in the model—feedstock supply costs ($ per bone dry ton (BDT) of biomass) and feedback yields (gallons/BDT) for the three types of feedstock (animal fats and yellow, plant oils, plant-based biomass)—is made difficult by the wide divergence in these values for the feedstock that can be used in producing drop-in fuels. Table A-IV shows a range of values for advanced biofuels feedstock for plants evaluated in the literature most capable for producing drop-in biofuels.

The 33 MGY KiOR plant (E2, 2012) is a real-world planned thermochemical pyrolysis renewable diesel facility reports a feedstock cost of $74 ($2012) per DT of biomass (Yellow Pine wood chips), and a yield of 67 gallons per DT. However, the studies of yellow grease, animal fat and several oil seed plants reports much more expensive feedstock, though yields appear to be higher, and construction and operating costs lower. There is insufficient data available for a definitive assessment of the costs and yields for the feedstock that would most apply to the drop-in fuel manufacturing case.

We therefore estimate a wide-range of potential values for each parameter, shown in the assumptions table A-I:

- The low-end values in the range are based on an average of costs ($70/DT) and yields (60 gallons/DT) for the woody residue/biomass and oil seed such as camelina feedstock sources.

– The high-end values of feedstock costs ($125/DT-equivalent) and yield (100 gallons/DT-equivalent).

Table A-IV: Production Costs and Yields For Different Feedstock in the Evidence

Source	Plant Size (MGY)	Feedstock Type	Feed Cost ($2012/DT)	Yield (gal/DT)
Parker (2011)	NA	Wood Chip (assumed)	$50.88	NA
Jones et al (2009)	76	Hybrid Poplar Wood Chips (Thermochemical F-T diesel plant)	$54.00	98.5
EPA (2010)	33.2	Biomass (Thermochemical F-T diesel plant)	$70.75	43.0
KiOR (Solecki et al, 2012)	33.0	Southern Yellow Pine mill chips	$74.00	67.0
IATP (2007)[9]	NA	Camelina (900–2,200 lbs./acre; $45–$68/acre)	$41-$151	NA
Parker (2011)	NA	Yellow Grease (*Source:* USDA Market News, 2009)	$519.00	NA
Bain (2007)	25-100	Soy oil, canola, palm oil, grease (renewable diesel plant)	$537.00	255.3
EPA (2010)	NA	Yellow Grease; $2012: 7.6 lbs/gallon fuel	$1.02/gal	0.13 gal/lb.

NA=Not available

The low-end values compare with $50 to $55 per BDT of cellulosic feedstock and assumed yield of 81 gallons of biofuels per ton feedstock, in 2012,[10] assumed by the *bio-era* (2009) study, keeping in mind these refer to cellulosic ethanol production plants and feedstock. The high-end values are based on an assumption that about one-tenth of the total fuels produced to meet the military alternative fuels targets very possibly would use animal fat and yellow grease feedstock. They are calculated using a weighted average of the biomass-based and animal fat/yellow grease feedstock values based on this assumption. In fact, we base the projected 75 MGY of capacity already online in the MBEIA model, on the Dynamic Fuels facility that has been producing drop-in diesel fuels for the military alternative fuels tests, using animal fat and waste feedstock.

The model's calculations of feedstock expenditures are carried out using the high and low feedstock costs for both the estimated high and low yield values. In the end, in calculating these expenditures, we use a wide feedstock yield range because, given the wide spectrum of available feedstock, we do not want not to prejudge how many plants would be built that used one type of feedstock or another

[9] Institute for Agriculture and Trade Policy (IATP), Rural Communities Program. "Camelina, Camelina sativa." Fact Sheet. January 2007.

[10] Bio-era. U.S. *Economic Impact of Advanced Biofuels*. 7.

(notwithstanding the existing 75 MGY animal-fat processing plant mentioned above that we assume would supply about one-tenth of the military's alternative fuel needs).

As with the construction costs, we assume that feedstock costs would decline over time, at a steady rate, by 20 percent by 2020, due to improvements in cultivating and/or preparing feedstock for processing. Feedstock yield is assumed to improve by 20 percent as well by 2020, contingent on improvements in process technologies and learning experience.[11] Finally, the calculated feedstock expenditures for the different feedstock cost and yield ranges are reduced by 10 percent to reflect the assumption that all the plants would be operating at 90 percent capacity.

Operating Expenditures Calculations

As in the case of the construction and feedstock costs, there is a wide range of possible values that vary greatly across the principal types of conversion technologies and the diverse kinds of biomass used in producing the drop-in biofuels for the military. A review of the literature and empirical data, part of which is summarized in table A-V, shows a wide range in the operating costs per gallon of fuel produced, depending on the conversion processes and feedstock employed in the various biofuel plants examined. The literature also shows that the costs are sensitive to plant capacity, as production costs per unit output tends to diminish with increasing economies of scale.

Table A-V: Operating Costs for Different Types of Plants in the Evidence

Source	Plant Size (MGY)	Feedstock/Conversion Process	Operating Costs ($2012)/Gal
EPA (2010)-CARB (2009) (High-Cost)	NA	Mixed Feedstock/Cellulosic F-T Diesel	0.44
EPA (2010)-CARB (2009) (Low-Cost)	NA	Waste Oil Feedstock	0.54
KiOR (Solecki et al, 2012)	33.0	Southern Yellow Pine mill chips/ Thermochemical Pyrolysis	0.67
Bain (2007)	25—100	Soy oil, canola, palm oil, grease/ Renewable diesel plant)	0.39-0.40
Chen et al (2012)	35—58	Pyrolysis	0.52-0.64
Chen et al (2012)	65	Thermochemical	1.34-3.50
Chen et al (2012)	12—177	Biomass-to-Liquid Diesel	1.39-4.02
Chen et al (2012)	29—38	Gasification	1.83-1.87

[11] Chen, Xiaoguang, Madhu Khanna and Sonia Yeh. "Stimulating Learning-by-Doing in Advanced Biofuels: Effectiveness of Alternative Policies." Department of Agricultural and Consumer Economics, University of Illinois at Urbana Champaign. 2012.

In selecting the operating cost per gallon to be used in the MBEIA model, we find that in the estimates from the different studies, one group of values tends to cluster in the $0.30-$0.70 range, with an average of $0.48 per gallon. A second, larger group of values range from $1.35 ($2012) per gallon to $4.02 ($2012) per gallon, with an *average* of $2.49 per gallon. Hence, we assume a range of $0.50 per gallon to $2.50 per gallon for the model, as shown in the assumptions table A-I. Operating costs are subsequently calculated for both the high- and low-end operating cost values.

Distribution Expenditures Calculations

To calculate the distribution expenditures for the drop-in biofuels that would be produced and then transported to the military's end-users, we assumed that the existing petroleum pipeline and transportation infrastructure (perhaps the military's own distribution system) would be used. This is made possible because the drop-in fuels have the same properties as the petroleum-based fuels. Corn-based and cellulosic ethanol and other alcohols cannot use this infrastructure, and consequently distribution costs would be somewhat higher. Using values provided by a National Academies study, we therefore estimate that transportation and distribution costs for the drop-in fuels would be only $0.02-$0.05 per gallon of fuel, as shown in the assumption table A-I.[12]

This is in contrast to *bio-era* (2009), which assumed a $0.23 per gallon distribution cost, noting that current transportation costs for ethanol in the United States typically range from $0.18 to $0.30 per gallon.[13] An Environmental Protection Agency report (EPA, 2010) estimated distribution costs of $0.20 per gallon for ethanol, $0.15 per gallon for cellulosic distillate or renewable diesel, and $0.20 per gallon for biodiesel,[14] which is a sum of capital costs and freight costs that be incurred in transporting these fuels.

Employment Impacts Calculations

In the MBEIA model, we assume a full-time equivalent (FTE) jobs estimate per MGY of plant capacity that would be created in the construction, feedstock production, and operations of new drop-in fuel production plants. We draw upon two sources for these sources. The E2 2012 market analysis estimated that plant construction would employ 10.29 workers per MGY of plant capacity, and plant operations would employ 2.24 workers per MGY of capacity. *Bio-era* (2009) assumed construction would require 20 jobs FTE per MGY of plant capacity and operations would employ an average of 0.9 operations jobs per MGY of plant capacity.

---

12 NRC. *Renewable Fuel Standard* 123

13 Bio-era. U.S*. Economic Impact of Advanced Biofuels*. 7.

14 U.S. Environmental Protection Agency (EPA). *Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis.* EPA-4200-R-100-006,. February 2010. 4.2.1-4.2.3.

The estimates from both sources are based on reasonable assumptions and reviews of the evidence—the E2 study's estimates are based on actual advanced biofuels and the *bio-era* numbers are based on a review of studies in the literature. At the same time, there also is a degree of uncertainty associated with the data reported in each source, as well, and they may be based on different assumptions of what kinds of jobs are actually covered in their numbers (e.g., *bio-era's* construction FTE estimate includes engineering, management and design jobs that may be offsite, as well as on-site construction jobs). We therefore use an average of the two estimates for the construction and operating jobs parameters.

However, we use *bio-era's* feedstock production jobs values to calculate the jobs associated with feedstock production. It is reasonable to assume that the jobs involved in biomass feedstock cultivation, production and processing for both cellulosic ethanol production and drop-in renewable diesel production for the military program are probably comparable if not the same. Since oilseed plants, such as camelina are similar to other agricultural products in their cultivation and harvesting (though perhaps not in their processing prior to delivery to a biofuel production plant), these value are likely comparable as well.

In our feedstock jobs calculations we also use *bio-era's* biomass yield per acre of energy crop (ton/acre) numbers, which incorporated an assumption of improved yield over time, which ranges from 9 t/acre in 2012 to 13 t/acre in 2020. Bio-era notes that "average yields per acre include all land projected to be used for cultivation for energy crops in the U.S."[15]

At the same time, because of a lack of data, we could not estimate possible jobs numbers that might be involved in animal fat/yellow grease, nor incorporate assumptions about jobs involved in gathering and preparing quantities of woody residues for use in biofuels production, we could not guess how this might affect the jobs numbers. This presents a degree of uncertainty about the actual numbers we generate using the MBEIA model that warrants greater study. However, this is currently the best data we have available at this time, and probably at least in the ball-park—the actual jobs we estimate to be created could just as likely be somewhat greater than smaller.

In sum we used the following FTE values in the MBEIA model to calculate:

- *Construction*: 15 jobs FTE per MGY of plant capacity.[16]
- *Feedstock production*: 5.6 jobs FTE per 1,000 acres of feedstock.[17]

---

15 Bio-era. U.S*. Economic Impact of Advanced Biofuels* . 7, table 2.

16 Bio-era. U.S*. Economic Impact of Advanced Biofuels; Mary* Solecki et al. *Advanced Biofuel Market Report 2012, Meeting U.S. Fuel Standards.* Environmental Entrepreneurs. 2012.

17 Ibid.

- *Operations*: 1.6 average operating jobs per MGY of plant capacity.[18]

Total construction and operations jobs are then calculated multiplying the jobs per MGY of capacity by the amount of capacity in operation for any one year and then summed over the 2013 to 2020 period. Feedstock jobs calculations, however, are more complicated:

- To calculate the total feedstock consumed (millions of BDT) in the production of the cumulative biofuels output for a given year, we divide the cumulative capacity (MGY) by the feedstock yield (gallons/BDT) using the low-end and high-end feedstock yield parameters;
- Dividing this total by average feedstock crop yield (DT/acre) values provided by *bio-era* (2009), gives us a high- and low-end estimate of total acres employed in growing feedstock consumed by the online production plants;
- Multiplying these numbers by the feedstock production FTE estimate (i.e., 5.6 jobs per FTE per 1,000 acres of feedstock) gives us a high- and low-end estimate of total direct feedstock jobs employed to supply the online drop-in biofuels output for a given year in our capacity scenario (table A-II).

Distribution jobs are estimated with the help of U.S. Bureau of Economic Analysis (BEA) Regional Input-Output Modeling System (RIMS II) multipliers that allowed us to estimate increases in employment in the pipeline transportation industry for each increase in final demand for the drop-in biofuels produced and sold to the military. We choose the pipeline transportation industry for this calculation based on our assumption that the new fuels will be distributed to its final users via the existing petroleum infrastructure.

First a direct-job multiplier is calculated by dividing the final demand employment multiplier (Type I) in the RIMS II multiplier table for the pipeline industry (9.9813) by the direct effect employment multiplier (4.6993), which gives us 2.1424. The final demand employment multiplier is defined as the total change in number of jobs that occurs in all industries for each additional 1 million dollars of output delivered to final demand for the given industry (pipeline transportation, NAICS 486000). The direct effect employment multiplier is defined as the total change in number of jobs in all industries for each additional job in the given industry.

Based on this calculation, therefore, we assume that there would be 2.1 distribution jobs for each additional $1 million of new biofuel output produced and delivered to the military. We then average the high and low estimate for total distribution costs for a given year (the low- and high-estimate costs per gallon of fuel multiplied by total online capacity (MGY) for that year (multiplied by the 0.9 capacity utilization adjustment)), on the assumption that the number of jobs operating and maintaining

[18] Ibid.

the pipeline would not be appreciably different depending on the high- and low values of the fuels flowing through the pipelines.

Calculating Economic Impacts

After specifying the various cost and yield parameters and various other assumptions associated with each value-chain sector, shown in the assumptions table A-I, the MBEIA model is used, first, to calculate the *direct* economic impacts—expenditures or outputs and jobs resulting from the production of drop-in fuels to meet the military alternative fuels targets over the 8-year period, 2013 through 2020. Then, applying the appropriate multipliers to the direct impact values, the model estimates the *indirect* and *induced* economic impacts that can be said to result from the military biofuels program.

Calculations of the direct expenditures or outputs and jobs created and/or supported for each value-chain sector have been discussed above. These impacts are calculated both for the individual value-chain sectors and for the total biofuels production sector as a whole, which is the sum of the individual value-chain sectors impacts. They are calculated for each year in the study period, 2013 to 2020, for the 8-year period in total, and the average impacts per year.

A distinction needs to be made between the impacts resulting from the construction of the plants, and the impacts associated with the production (including feedstock and operations) and distribution of the fuels delivered to the military end-users. Although the direct output and jobs associated with plant construction are temporary, the indirect and induced impacts from construction may last over a period of time after construction is completed, as the expenditures pumped into the economy ripple downstream stream through the construction supply chains.

The production and distribution impacts are cumulative, growing every year as new biofuels production capacity goes online, as new plants are built, until the full 770 MGY of capacity (including existing, currently planned and newly added capacity) needed to meet the military's goals by 2020 is installed. The calculated impact values for any or all the production and distribution sectors at the end of the period are the cumulative impacts that are calculated for the year 2020.

We then calculate the downstream indirect and induced impacts, applying the appropriate multipliers determined using the BEA's RIMS II model, based on the estimated direct output and employment impacts. For both kinds of impacts, we calculate new economic *outputs* (sales), *jobs*, and *value added* resulting from the economic activity stimulated by the military biofuels purchases. Value added is the gross output of an industry less its intermediate inputs, and represents the contribution of an industry or sector to gross domestic product (GDP).

The RIMS II model provides two types of multipliers for calculating these impacts—Type I multipliers, which can be used to calculate the indirect impacts and Type II

multipliers, which can be used to calculate the induced impacts. Multipliers are typically used in regional economic analyses, and multipliers provided by BEA usually are specific to the region and industry sectors under study. However, the BEA can also provide multipliers for larger regions, which incorporate several contiguous smaller geographical regions. Since the focus of the MBEIA model and our analysis is national, we used multipliers the BEA calculated for a large region comprised of the 48 contiguous states in North America (not including Alaska or Hawaii) and the District of Columbia.

Each industry has its own multipliers for calculating these impacts based on changes in its output and jobs resulting from a final demand change, such as the military biofuel purchases. In the model, we use multipliers for industries that are most similar to the sectors in the military biofuels value chain:

- The *construction industry* (NAICS 230000) and the biofuels construction sector in the biofuels value-chain.
- The *oilseed and grain farming industry* (NAICS 1111CO) and the feedstock production sector,
- The *other basic organic chemical manufacturing* (NAICS 325190) and the biofuels operations/production sector; and
- The *pipeline transportation* (NAICS 486000) industry and the biofuels distribution sector, as noted above.

These multipliers are summarized in table A-VI below. The indirect and induced output, value-added and earnings impacts are calculated by multiplying the appropriate multipliers by the direct outputs for each value-chain sector.

Table A-VI: Multipliers for Military Biofuels Value Chain Impacts

Industry/ Multiplier	**Construction** *(Construction)*	**Feedstock** *(Oilseed & Grain Farming)*	**Operations** *(Basic Organic Chemical Manuf.)*	**Distribution** *(Pipeline Transportation)*
DIRECT & INDIRECT IMPACTS (TYPE I)				
Output ($)	1.84	2.12	2.47	2.12
Jobs	1.58	3.65	4.75	4.70
Value Added ($)	0.93	0.89	0.78	0.84
DIRECT, INDIRECT & INDUCED IMPACTS (TYPE II)				
Output ($)	3.09	2.89	3.44	3.22
Jobs	2.60	5.64	9.05	8.58
Value Added ($)	1.64	1.33	1.33	1.46

Notice that the calculations provide either a combined direct and indirect impacts (Type I multipliers) or combined direct, indirect, and induced impacts (Type II multipliers). For example, multiplying the feedstock sector's direct output (high estimate) for, say, 2020 ($0.96 billion) by the appropriate direct and indirect (Type I) multiplier in table A-VI (2.12) yields the total direct and indirect output (high estimate) for that sector ($2.04 billion), for that year. Indirect impacts and induced impacts can also be calculated: the former by subtracting direct impacts from the combine Type I indirect and direct impacts, which yields $1.08 billion in the feedstock output example; the latter by subtracting Type I impacts from the Type II (direct, indirect, and induced impacts), or $0.74 billion ($2.78 billion minus $2.04 billion) in the example.